N. V. Sripathy

Tropical Products Institute

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An introduction to fish handling and processing

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SUMMARY

This report presents notes for twelve lectures which, in conjunction with practical demonstrations and audio-visual aids, provide the basis for a one-week training course suited to middle-level administrators and managers. These notes range broadly over all post-harvest aspects of handling, preservation, processing and storage of fish. Chilling, freezing, salting, drying and smoking are described in detail with illustrations of the different types of processing equipment available. The various instruments used in the fish processing industry are also described.

RÉSUMÉ

Une introduction a la manipulation et la préparation du poisson

Ce rapport présente les notes prises au cours de douze conférences qui, conjointement avec des démonstrations pratiques et avec l'utilisation de l'audiovisuel, donnent les bases de l'enseignement dispensé au cours d'une semaine de formation s'adressant aux administrateurs moyens et aux directeurs. Ces notes décrivent en détail tous les aspects de la manipulation, de la conservation, des méthodes de préparation, et de l'entreposage du poisson après la récolte. La réfrigération, la congélation, le salage, le séchage et le fumage sont décrits en détail, avec illustration des différents types d'équipements utilisables dans les processus de transformation. On décrit aussi les divers instruments utilisés dans l'industrie de transformation du poisson.

RESUMEN

Una introducción al manejo y elaboración del pescado

Este informe ofrece notas para doce conferencias las cuales, en conjunción con demostraciones prácticas y ayudas audiovisuales, constituyen la base de un curso de adiestramiento de una semana de duración orientado hacia administradores y directores de nivel medio. Las notas tratan de manera general sobre todos los aspectos del manejo, conservación, elaboración y almacenaje de pescado. Se describen de manera detallada los procesos de enfriado, congelado, salazón, secado y ahumado, y se incluyen ilustraciones de los distintos tipos de equipos de elaboración disponibles. También se describen los diversos instrumentos utilizados en la industria de la elaboración del pescado.

Introduction

The following notes for 12 lectures are designed to form the basis for a 5–6 day course of training for middle level fisheries administrators and managers. Each session should last 1 to 1½ hours, probably with a short break in the middle. The course for which these notes are designed must include demonstration and practical work if the students are to gain fully from the effort involved. The course would normally consist of lecture and discussion sessions in the mornings and practical work/demonstrations in the afternoon. The following 'practicals' and demonstrations are recommended.

1. Fish cutting, filleting etc., measurement of yields.
2. Demonstration of correct icing with construction of cooling curves.
3. Use of instruments.
4. Freezing trial to demonstrate thermal arrest, freezer burn etc.
5. Visual assessment of quality on fish stored in ice for different lengths of time.
6. Taste panel assessment of quality and use of Torrymeter.

In addition, liberal use of overhead projector, blackboard, colour transparencies and films is recommended. A list of suitable films is given in the appendix.

The importance of fish in the world

PRODUCTION

Fish is an important component of diet for people throughout the world. Total world production of fish has risen from about 20 million tonnes in 1938 to more than 73 million tonnes in 1976. The per capita consumption of fish for human food in 1970 was 11.8 kg, a figure which varies considerably from country to country.

In the developed countries of North America, Western Europe, Oceania etc. consumption rates are generally much higher than those of the less developed countries. Robinson estimated the following per capita consumption rates for 1970.

	kg/head
World average	*11.8*
Developed countries	*23.5*
N. America	15.4
W. Europe	20.3
Oceania	12.4
Others	47.5
Developing countries	*7.4*
Africa	7.1
Latin America	6.5
Near East	2.4
Asia	8.5
Centrally planned	*11.3*
Asia	8.1
USSR	23.9
Eastern Europe	8.7

However these figures mean little without relating them to the intake of other animal proteins. On a global basis fish represents about 14 per cent of all animal protein consumed but once again there are wide variations from country to country.

Countries of South America tend to have high meat consumption compared with fish whereas the countries of the Far East and Africa have higher percentages of fish. In general the more developed countries of Europe and North America have a higher overall animal protein intake. The following table illustrates this point.

Country	Fish as percentage of animal protein supply 1964–66	Per caput consumption kg per annum of fish and meat 1970
Argentina	2.5	125.5
Uruguay	1.5	137.5
UK	7.9	98.1
USA	4.8	124.3
Indonesia	65.4	14.7
Japan	57.8	76.4
Burundi	39.2	8.4
Jamaica	41.5	55.0
Haiti	6.4	9.3
Dominican Republic	26.6	25.7
Burma	52.2	23.5

This table also illustrates the wide variation in total animal protein consumption/capita. Generally speaking the higher income countries have higher intakes of animal protein.

EMPLOYMENT

Another important contribution of the fishing industry is that of employment. It is reckoned that between 8 and 10 million people are engaged as fishermen and that probably an equal number are employed in service industries to the primary producers as fish traders, processors, mongers etc. Of this vast number of people involved a large proportion are self-employed and work at the subsistence level. Industrialised fisheries of the developed world tend to employ relatively small numbers of people producing large quantities of fish whereas the small boat subsistence fisheries of the developing world produce small quantities of fish from a large labour force.

For example, the approximately 5,000 Icelandic fishermen produce more than 150 tonnes of fish each/year whereas 23,000 Malawian fishermen produce approximately 3 tonnes of fish each/year. In the Dominican Republic it is estimated that the 6,000 full and part time fishermen produce a little over 1 tonne of fish each/year.

THE STRUCTURE OF FISH

The main components which go to make up the body of a typical teleost are as follows:

(i) *The skeleton*

Consisting of skull, backbone, rib cage and fin supports.

(ii) *The musculature*

Mainly white muscle supported by the skeleton.

(iii) *Skin and fins*

Skin is often scaly in teleosts.

(iv) *Viscera*

Alimentary canal and associated organs and the urinogenital system.

Fish processors often talk of the head as a separate organ as it is often removed complete. However, it is composed of some skeletal material (the skull), some skin, has some musculature and associated sensory organs, e.g., eyes, brains etc.

By far the most important component of the fish as far as the food processor is concerned is the musculature. This is the most often eaten component and is frequently removed from the rest of the fish as fillets and treated separately.

It must be remembered that, when the fish is to be filleted, catch weights mean nothing without having a figure for the fillet yield. The white muscle makes up about 30–40 per cent of total body weight but varies considerably depending on size and shape of the particular species of fish.

The physical components of cod, as a percentage of whole body weight, are as follows:

	Per cent
Head	21
Viscera	16
Skeleton (excluding skull)	14
Skin and fins	13
Fillet	36

COMPOSITION

In general terms we can say that fish muscle has the following proximate compositions: 20 per cent protein; 5 per cent fat; 5 per cent ash; and 70 per cent water. These proportions may vary considerably, for instance, cod, a non-fatty white fish, has approximately 80 per cent water, 18 per cent protein, 0.1 per cent fat and 1 per cent ash whereas herring flesh can contain 60–90 per cent water, 10–19 per cent protein and 2–22 per cent fat depending on the season and the sexual and nutritional state of the fish. Some fish can even have protein contents as high as 25 per cent or more, for instance, skipjack tuna.

Protein

Fish is mainly thought of as a source of protein. Twenty per cent of the weight of fish flesh is protein. Without protein, the human body is unable to grow. Fish protein compares favourably with eggs, milk and meat in its amino-acid composition and, in fact, often has higher levels of essential lysine and methionine both of which are lacking in a cereal-based diet. This makes fish protein particularly valuable in many countries where the staple diet consists of cereal (e.g. mealie meal, cassava, yam, rice, potato etc).

Fat and vitamins

Most fish contain fairly high levels of fat or oil. Some of the fatty fish contain 20 per cent or more in their flesh whereas white fish contain little oil in their flesh but large quantities can be extracted from their livers. Fish fat is characteristically high in poly-unsaturated fatty acids making them important in diets for people requiring to keep low levels of cholesterol in their blood. Fish oils contain fairly high quantities of vitamins especially A, D, thiamin, riboflavin, nicotinic acid and B_{12} making them even more important in vitamin deficient diets. Processing however can adversely affect the quantities of vitamins present, for example, canned tuna only contains about 25–30 per cent of the thiamin originally present.

Minerals

Fish contain quantities of minerals which are important in diets. When a fish is filleted and the head, bones and skin discarded, much of the mineral content is lost. However, where small fish are eaten whole, then the mineral content of the skin and bones can be important. The main mineral constituents present are calcium and phosphorus in bones, iron in liver, and magnesium and copper which are important trace elements.

CONCLUSION

Fish constitutes a very important component of diet for many people and often provides much needed nutrients not provided elsewhere in cereal-based diets. The lack of livestock and fresh meat production in many countries makes fish protein all the more essential. Anything that can be done to increase fish production in these countries will go some way to filling the gap between malnutrition and health.

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An introduction to fish spoilage: methods of preservation

Fish is an extremely perishable foodstuff. Spoilage of fish begins as soon as the fish dies or is caught. In the high ambient temperatures of the tropics, fish will spoil within 12–20 hours depending on species, method of capture etc. A fish such as cod from colder waters would spoil in less than 2 days if kept at 20°C but, at a temperature of around 5°C, could remain acceptable for about 5–6 days.

Spoilage is the result of a series of complicated changes brought about in the dead fish mainly by enzymic and bacterial action. Before we consider how these bacteria and enzymes perform, and how they can be controlled in order to prevent or reduce spoilage, let us look very briefly at what is happening in the living animal.

The tissues of live fish are in a continual state of change. As in all living creatures with an alimentary canal, food is taken in and is digested, i.e. broken up into smaller units which are absorbed through the wall of the intestine into the bloodstream. These units are transported to various sites in the body, e.g. the muscle or flesh, where they can be used to produce essential larger components or energy; compounds which are no longer required are broken down. Enzymes are responsible for these changes. Enzymes are biological catalysts and belong to the class of compounds called proteins. They make reactions, changing one substance to another, proceed at a faster rate without themselves being changed. In order to make the larger units, from the pool of smaller units which is present at all times in the tissues, a source of energy is also required.

Bacteria are the smallest free-living organisms known. Although they are so small (over a million would fit on a pin head), they perform an essential role in the natural life cycle on Earth. They are found practically everywhere in nature; they can grow and reproduce and can break down complex substances into simple units. Without bacteria, the natural decay of plant and animal material could not take place. Bacteria are found in large numbers on the surface, on the gills and in the alimentary canal of live fish. The natural defence mechanisms of the fish prevent the ingress of bacteria into the tissues. They feed, grow and multiply outside the fish tissues, which, in the live and healthy fish, are sterile.

WHY FISH SPOIL

Immediately the fish dies, however, certain irreversible changes begin to take place. Within a few hours (or more), the muscles gradually harden along the fish until it is quite stiff. The fish can remain rigid for a number of hours or a few days depending on various factors. The muscles then 'soften' or become pliable again. This stiffening is known as *rigor mortis* and is brought about by enzymes in the muscle. It is important in relation to filleting operations and will be discussed in a later lecture. Also the enzymes of the flesh cause a complicated series of breakdowns, of other tissue components, known as autolysis (or self digestion). In addition bacteria and,

in the case of ungutted fish, digestive juices, invade the flesh to start the process of putrefaction. Lastly, fat is attacked by oxygen and can give rise to rancidity.

Autolytic spoilage

At death, the supply of food ceases and the energy resources soon become depleted. The enzymes do not 'die'; they can continue to operate but, since energy is required to build larger units, the function which the enzymes perform post mortem is to break compounds into smaller units. This breakdown of tissues is known as autolysis. Autolysis can affect the flavour, texture and, sometimes, the appearance of the flesh.

Flavour The characteristic sweet, meaty flavour of fresh fish is due, at least in part, to a compound called inosinic acid; its breakdown through autolysis results in loss of this flavour. Another compound, hypoxanthine, which is produced from the breakdown of inosinic acid, contributes to the bitter flavours of spoiled fish. Autolysis also contributes indirectly to fish flavours by providing a supply of compounds which the bacteria convert to unpleasant flavours (and odours).

Texture The stiffening of fish (*rigor mortis*) and the subsequent softening are caused by autolysis. Rigor is of great significance in fish processing particularly in freezing operations for very fresh fish i.e. freezing at sea. In rigor, the fish can stiffen into distorted shapes and they can then be difficult to load between freezer plates. Forcibly straightening the fish can lead to serious textual damage in the flesh when filleted. Fillets, cut before rigor and then frozen can contract during storage giving a tough rubbery texture.

Appearance Yellowish-brown discolorations which are sometimes present in frozen flesh could be due to autolytic action.

Bacterial spoilage

When the fish dies, bacteria present on the surface and in the guts, multiply rapidly and invade the flesh, which provides an ideal medium for growth and multiplication. The bacteria can break down the muscle itself and also will 'feed' on the smaller units produced by autolytic action. The increase in numbers of bacteria results in heavy slime on the skin and gills; an unpleasant ammoniacal, sour odour and eventual softening of the flesh. Frequently the gut wall will burst.

The bacterial load present on the fish when caught will continue to multiply (even if thoroughly chilled in ice) until the fish is consumed. However, during handling they are likely to pick up more bacteria, from washing in polluted water, careless gutting, dirty boxes etc. etc. However careful you are in handling the fish there will always be bacteria present but, with care, the numbers can be controlled.

It was noted earlier that the flesh of living fish is sterile. From experiments it has been shown that, if blocks of muscle are removed asceptically and maintained under sterile conditions at 0°C for up to 6 weeks, there are no serious organoleptic changes. Autolytic changes will, of course, be occurring during this period.

Oxidation of fat

In fatty fish, chemical changes involving oxygen from the air and fat of the fish may produce rancid odours and flavours. This problem is of importance when storing frozen fish for fairly long periods. Glazing before cold storage helps to alleviate the problem.

METHODS OF PRESERVING FISH TO REDUCE SPOILAGE

Bacterial and autolytic spoilage are biological systems which operate only under certain optimum conditions. Thus altering the conditions can provide ways of preventing or reducing spoilage. Since bacteria require water and are sensitive to heat, salt concentrations and pH, there are a number of approaches which can be

used. Control of autolysis is, by definition, control of enzyme activity. By far the most common and practical way of reducing autolytic action in the fishing industry is by lowering the temperature but enzymes could also be inactivated by other means, e.g., irradiation or poisoning by chemicals.

Temperature control

The bacterial flora of fish and the enzymes present in the tissues are adapted to the temperature at which the fish lives, i.e. around 5–10°C for fish from cold waters and 25–30°C for tropical fish. By lowering or raising the temperature, bacterial and autolytic spoilage rates will be reduced.

Lowering the temperature In broad terms it can be said that the lower the temperature, the slower the bacterial and enzyme activity and, consequently, the longer the storage life. Thus fish can be either chilled, usually in ice, or frozen.

Chilling: is holding fish just above (or at) their freezing point. In tropical climates this would mean that the temperature of the fish would be reduced from say 25°C to 1–4°C. Ice is an ideal medium for chilling; more and more fisheries are now using ice to chill the catch. Ideally, fish should be chilled as soon as possible whether they are to be used fresh, frozen, dried etc. Storage in ice is 'short-term' although for some species this can be as long as a month.

Freezing: is for long term storage. The much longer storage life, of many months to a year, is due to the following:

(1) autolytic and bacterial action are almost completely halted at the recommended frozen storage temperature, –30°C.

(2) water is effectively removed by being 'locked away' as ice.

Whilst the long shelf life of frozen fish is to be desired in a number of situations (particularly for high-value products which are exported and for storing excess amounts of fish in highly seasonal fisheries), in many others a freezing operation would be totally unnecessary. Furthermore, the plant needed for freezing and storage of frozen fish is very expensive to buy and costly to run.

Raising the temperature Generally this involves cooking the fish, for example, canning, boiling and smoking. Smoking is more easily considered later.

Canning: the fish are subjected to high temperatures to kill the bacteria and inactivate enzymes. The inside of the can must be resistant to the contents and the outside resistant to ambient conditions. The can must be hermetically sealed. Canned fish will keep for long periods but canning is an expensive process. Canning operations are generally successful only on a large commerical scale, for species such as tuna, sardines etc.

Boiling: the fish are boiled with or without salt and the shelf-life can be extended by a few days under tropical conditions. Boiled fish is popular in South East Asia. In some places, the fish is then dried to give a longer shelf life.

Removal of moisture

The moisture content of fish is about 80 per cent; if this is reduced to around 25 per cent bacteria cannot survive and autolytic activity will be greatly reduced. At moisture contents of 15 per cent or less, moulds will cease to grow; well dried fish, if stored under the right conditions, can be kept for several months.

Drying techniques: drying can be carried out alone or in combination with smoking or salting. Whether the fish are dried, smoke-dried, or salted and dried the aim is to remove the moisture as quickly as possible, before spoilage occurs.

There are various ways of drying fish.

Fish can be dried naturally in the sun by using the sun's energy to drive moisture out. If they are very small they can be left whole, otherwise they should be split to increase the surface area. Sun drying has a number of disadvantages but the main

advantage is that the energy is 'free'. The sun's energy is also used in solar driers and 'Black Box' drying, but these systems are still experimental.

In colder climates, e.g. Iceland and Norway, wind is the main agent that dries the fish. Because the air temperatures are very low, spoilage is slowed down. The fish are headed and gutted (and split if large) and hung in the open air for up to 6 weeks until hard and dry. This type of product is called stockfish.

Traditional drying by sun and wind is slow and at the mercy of the weather. With mechanical driers it is possible to control the temperature, humidity and air flow but fuel, e.g. electricity or oil, which is very expensive in many countries, is required to run the heaters and fans.

Smoking: In many tropical areas fish are smoked over open fires or in simple kilns in order to accelerate the drying process. If the relative humidity is high and salt is scarce (as is often the case in many African countries), hot smoking, where the fish is cooked (and often charred), is the only method of preserving fish. Wood or some other locally available combustible product is used.

Cold-smoked products, in which the flesh is not cooked, are enjoyed in many developed areas of the world. Smoking is carried out more as a means of giving a desired flavour rather than as method of preservation; refrigeration is necessary in order to keep such products. Cold smoking is rarely carried out in the tropics.

Throughout the world many different types of fish are smoked by a variety of smoking methods. These range from traditional processes in which the fish are smoked over open fires or in simple smoking ovens or kilns, to improved processes in vertical kilns and, particularly in developed countries, in sophisticated mechanical kilns.

Salting: Salt is often used in conjunction with drying and smoking. If salt is rubbed into the flesh or if the fish are placed in brine, water is removed and salt passes in by what is called osmosis. As most bacteria cannot grow in salt concentrations above 6 per cent, salting will, therefore, reduce bacterial action. There are, however, groups of bacteria that like a salty environment, i.e. they are halophilic, and these can cause problems in salted fish.

Other methods

Here we will look briefly at marinades, and fish sauces and pastes.

Marinating: Marinating, i.e. placing fish in a dilute acid and salt solution, slows down the action of bacteria and enzymes but some will remain active and the flesh will eventually break down. In a moderately acid solution most spoilage bacteria are, however, prevented from growing. Marinades are semi-preserves. The aim of marinating is to produce a pleasant tasting product which is not too tough and which has an extended shelf life. It is not necessary to keep the marinade in a refrigerator but, if it is, the shelf life can be extended to several months.

Fish sauces and pastes: These are used as condiments i.e. flavouring agents; they are extremely popular in South East Asia. The methods of preparing sauces and pastes are somewhat different but, basically, small fish or shrimp are mixed with salt and allowed to ferment. The fish break up and finally a paste or sauce of characteristic flavour and odour is produced.

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Wet fish handling and preparation

There are many different types of fish products available to the consumer but most of them will have undergone some sort of initial preparation before processing. This preparation can be in the form of cutting the fish in a particular way to produce the raw material necessary for future processing. Because of the delicate nature of the fish and the rapid rates of deterioration that can occur if the fish is treated badly it is extremely important to handle it hygienically and carefully during all stages of preparation. This session is designed firstly to clarify some of the ways in which the initial preparation can be done and, secondly, to give guidelines to the hygienic preparation of fish before onward processing.

DEFINITIONS OF SOME TERMS USED IN FISH PREPARATION

1. *Fillet* – a strip of flesh cut from the fish parallel to the line of the backbone.

Block fillet – flesh from both sides of a single fish joined together, usually along the backbone.

Single fillet – flesh from one side of the fish.

Fish can be filleted either by hand using knives or, for many of the more common European and American species, using filleting machines.

Fish is often filleted prior to sale fresh and prior to freezing, smoking, canning and production of mince products.

2. *Gutted fish* – fish from which the guts have been removed.

Gutting is often done at sea prior to storage on ice or before freezing in vertical plate freezers on 'freezer trawlers'.

Gutting is usually achieved by cutting the fish along the ventral surface from the vent to the gill opening and removing the intestines. In many cases the head is removed at the same time as the fish is gutted.

3. *Split fish* – fish is often split during preparation for smoking or drying. The purpose of this is usually to increase the surface area of the fish so that it can dry more quickly or take up flavours of salt, smoke or other condiments used during processing more uniformly.

Most of the methods used for splitting fish remove the guts but do not remove bones except perhaps for the head.

4. *Boned fish* – the flesh of the fish from which most of the bones have been removed. For instance a fillet may contain some small pin bones or ribs but it is often described as boned.

5. *Boneless fish* — flesh of the fish from which *all* the bones have been removed.

6. *Dressed fish* — fish which has been prepared for cooking or prepared in a particular way for presentation purposes.

GUTTING FISH

It is normal practice in many fisheries in temperate waters for fish to be gutted as a matter of course as soon as they are landed on the deck of the catching vessel. Gutting of cod for instance is so routine that a whole cod fish is almost impossible to buy in the UK and the trade talks of gutted cod as whole fish. The purpose of gutting is to remove one of the major bacterial concentrations from the fish and so minimise the risk of contamination of the fish flesh by gut bacteria. It is generally accepted that cold water white fish keep better in ice when gutted. The little work that has been done on tropical species suggests that there are advantages in gutting tropical fish but these are often marginal and in many communities there is a resistance from the consumer to accepting fish that is not whole. For this reason it is often not practical or advantageous to gut fish in tropical developing countries. When gutting it is extremely important that all the guts are removed, the belly wall of the fish is not broken and the belly cavity is thoroughly washed after gutting. If this is not done, the bacteria which are released from the guts during removal will contaminate the flesh and the whole operation will have been in vain.

FILLETING

A high demand for convenience foods in the developed world constitutes a large market for boned fish. The majority of fish eaten by people in the UK and Western Europe is prepared in processing factories into fillets or other convenience products before it is distributed to wholesalers and retailers, often as a frozen product.

Fillets must be prepared with great care and under strict conditions of hygiene because the flesh, once cut from the body of the fish, is very susceptible to the action of bacteria on its large exposed surface area.

The phenomenon of rigor mortis is important as far as the fish filleter is concerned only when he is handling very fresh fish which have not yet entered rigor or are actually in rigor. If a fish is filleted pre-rigor the fillet will enter into a state of rigor off the bone and since the skeleton will not support the flesh the fillet will shrink as the muscles contract. If the fish is in rigor during filleting the physical difficulties of cutting the rigid fish will probably produce a bad fillet which will shrink once removed from the bone. These problems usually only occur when filleting on board fishing vessels at sea.

HYGIENE

Bacterial contamination of fish flesh is a major cause of spoilage and if the flesh is contaminated by pathogenic bacteria it can cause serious illness or even death amongst consumers. If fish are kept clean and at chilled temperatures contamination can be kept to a minimum and the growth of any bacteria that are present is reduced.

One of the most important requirements when we handle fresh fish is that of adequate supplies of clean water. More than 90 per cent of the bacteria present on the surface of fish can be removed by thorough washing with clean water. The water should be filtered and chlorinated; otherwise it may introduce bacteria to the flesh of the fish which may be pathogenic, and in the long run do more harm than good. Water which is going to come into direct contact with fish should be of similar quality and intensity of chlorination as drinking water, i.e. about 0.1 to 0.3 ppm residual chlorine. Water used for washing down premises etc. can and should be of higher residual chlorine which could be up to 20 or 30 ppm.

Cleanliness is required at every stage of fish handling and preparation. All working surfaces must be made from materials which do not soak up water and they should be cleaned daily. Similarly all equipment and tools must be kept clean. Personal hygiene of staff is essential, and adequate washing facilities including the provision of soap, brushes and clean towels should be available and should be used before commencing work, after handling any contaminated materials, and after going to the lavatory.

Metal working surfaces, sinks etc. are preferable, as are composition cutting boards. Wooden cutting boards of a suitable non-resinous hardwood are permissible, but additional care should be taken to ensure their cleanliness. Floors should be waterproof and well drained.

At the end of each working day all surfaces should be thoroughly washed down with suitable detergent. The handling which fish receives before and during preparation will affect the quality of the final product. Fish should be kept in boxes or similar containers and should not be piled on the floor, nor should they be thrown around or walked over.

Cut fish are more liable to bacterial contamination than whole fish and tools and equipment must be clean. Fillets should be processed or packed and chilled immediately after preparation.

Fish should at all times be handled with care to prevent physical damage (fish flesh is easily bruised), it should be clean and kept clean. Wet fish should be at chill temperature, and should be shielded from direct sunlight, particularly in the tropics, where ambient temperatures are high. Fish deteriorate very rapidly at high temperatures.

REQUIREMENTS FOR FISH HANDLING PREMISES

Detailed below are outlined specifications for buildings in which fish are handled and suggestions for a code of practice that should be followed when handling fish.

1. Where possible, all preparation, processing and packaging should be carried out in one building.

2. Buildings should be single storeyed, since drainage and handling fish is easier on a single level.

3. Floors should be smooth surfaced but non-slip, well drained and waterproof. As far as is possible they should be resistant to attack by fish oils, offal and brine. High density concrete containing granite chips can be used although clay tiles are better.

4. The floor surface should be carried up the walls or any permanent fixtures for a height of at least 15 cm (6 in).

5. Floors should slope into the drainage system to facilitate washing down.

6. Drainage channels should be accessible and traps should be installed before discharge into any sewer or soakway. Traps should be easily and frequently cleaned. Drainage channels should be arranged away from through areas; if not , they should be covered with flush fitting removable gratings.

7. Walls should be waterproof and have a smooth surface. Tiles can be used on walls where the working tables are against the wall. All other wall surfaces should be painted, preferably with a hard gloss paint.

8. Doors should be flush fitting and well painted to give a waterproof and washable surface.

9. Windows should be of simple construction with a few large sheets of glass, not numerous small sheets.

10. All metalwork should be painted thoroughly to prevent rusting.

11. In tropical countries efficient fly screening is essential. All doors and openable windows should be screened. Self closing screen doors should be fitted at all normal points of entry and exit to and from the working areas.

12. Ceilings should have, as far as is possible, a continuous unbroken surface, be painted in a light colour and easily washed. In tropical climates insulation above the ceiling may be required to reduce over-heating.

13. Good ventilation is essential and in the tropics all ventilation openings must be screened. In very hot and humid climates an air-conditioning system may be justified. In this case a qualified engineer should be consulted.

14. All equipment must be easy to clean. All work surfaces should be of stainless steel or aluminium alloy. Cutting boards of composition material are preferable but if not available, cutting boards of hard non-resinous wood should be used.

15. Containers for fish and brine should be made from stainless steel, aluminium alloy or a suitable plastic. Wooden fish boxes can be used but they are more difficult to keep clean.

16. All electrical installations should be properly earthed with waterproof power points. They should be sited well above floor level.

17. A piped supply of clean, drinking quality water should be available. If suitable piped water is not available a filtration and chlorination plant should be installed to treat the raw water supply.

18. A regular cleaning routine must be established for the whole premises to ensure that standards of hygiene are maintained. It is important that adequate supervision is given during cleaning.

19. Detergents and sterilants should be used for cleaning. Detergents help to remove dirt, sterilants kill bacteria. Many detergents also have sterilising properties. A detergent should be used to remove dirt followed by a sterilant to kill any remaining bacteria. If water chlorination equipment is on site, high levels of chlorine in the water can be used to sterilise.

20. A piped hot water supply should also be available. Detergents are far more effective when used in hot water.

21. High pressure hoses should be used for washing down if at all possible.

22. Adequate washing, changing and lavatory facilities should be installed but not in the fish working area. Washing facilities should also be installed in the fish working area.

KNIVES

Knives form an important part of a fish processor's equipment. There are various types of knife used in fish preparation which have specific uses. However, there are many makes and designs of knife all with the same function. It is often a matter of personal preference as to which knife a particular fish processor uses.

The filleting knife is usually a long, thin-bladed instrument. The blade can be anything from 15 to 20 cm long and it is often only 1 cm or so wide. The blade needs to be slightly flexible so that it can bend when put under pressure during the filleting operation. The knife used for block filleting is a short-bladed knife about 7 to 10 cm long by about 1 cm wide with some flexibility to accommodate pressure during use. The gutting knife has a short-blade often only 5 to 7 cm long which does not need to be very flexible.

Traditionally, fish knives have been made of tempered carbon steel with wooden (usually rosewood) handles. These knives have the great advantage of being easy to sharpen and keep sharp once sharpened. However, without regular cleaning the blades

can rust and the handles become waterlogged and therefore difficult to clean. Recently, there has been a change to stainless steel bladed knives which have the great advantage that they do not rust. However, a stainless steel knife will not sharpen as well as a normal steel knife nor keep its edge for so long. With the introduction of stainless blades has come the use of moulded plastic handles for fish preparation knives. These are easily cleaned and very hard wearing compared with wooden handled knives.

Sharpening knives. It is extremely important that all knives that are used during fish preparation are sharp. A blunt knife will not cut fish flesh smoothly and the resultant cut will be ragged and unsightly.

There are essentially three stages to producing a sharp knife which are as follows:

1. Grinding the knife edge to the correct profile and shape to enable it to be sharpened. Grinding is usually done on a wet rotary grindstone, lubricated with water. It can also be done on the coarse side of a double sided carborundum oil stone. It is usually only necessary to grind a knife very occasionally, either when it is new or when it has been mistreated and the edge has become broken or distorted.

2. Sharpening the knife edge to a V shape on the fine side of a carborundum stone lubricated with oil.

3. At the end of stage 2 the edge of the knife will be sharp but not absolutely smooth. A 'steel' is used to take out the minor imperfections in the edge of the blade. Steeling is done as little or as often as the knife is used. No amount of steeling will sharpen the knife once it has become blunt.

Chilling: properties, manufacture and storage of ice

Chilling is an extremely effective way of reducing spoilage if fish are chilled quickly and kept chilled, and are handled carefully and hygienically. The objective in chilling is to cool the fish as quickly as possible to as low a temperature as possible without freezing them. Chilling can never prevent spoilage but, in general terms, the colder the fish are, the greater the reduction in bacterial and enzymic action. In freezing, bacteria are killed or are inactive and enzyme action proceeds only very slowly, provided the fish are frozen to a sufficiently low temperature. Chilling and freezing are, however, two completely different operations. If you want to chill fish, they must not be allowed to freeze for reasons which will become evident in a later lecture.

In order to chill fish they must be surrounded by a medium which is colder than the fish. The medium could be a liquid, a solid, or gaseous but, of the alternatives that could be used, you will see that ice has a lot in its favour.

ICE VERSUS OTHER COOLING METHODS

We will look at the reasons why ice is such a popular cooling agent compared to other methods, e.g. mechanical refrigeration, cooled sea water and other low temperature materials.

Ice

Ice is an ideal cooling medium. It has a very large cooling capacity for a given weight or volume, it is harmless, comparatively cheap and can cool the fish quickly through intimate contact between the fish and ice. For effective chilling, the ice must be allowed to melt and, furthermore, the melting ice also keeps the fish moist and glossy.

Ice is its own thermostat and, since about 80 per cent of the total weight of fish is water, the fish are maintained at a temperature slightly above that at which they would begin to freeze. Another advantage of ice is that it can be fairly easily transported; it is a 'portable' cooling method. Transportation, however, will increase the cost of the ice and, unless it is well insulated in transport, it will melt. Of the two basic types of ice which are made (block ice and 'small ice'), block ice melts less quickly and is therefore preferred in a number of situations. Block ice does, however, have to be crushed by hand or by machine and the resultant pieces of ice are less uniform in size than the 'small ice' and, because of the irregularities in size and shape, can damage the fish and will not make such good contact with the fish.

Ice is comparatively cheap, i.e. it is cheap in comparison to other ways of chilling. However, in many tropical countries ice is still very expensive. It tends to be cheaper when made in large quantities but again, if it is transported, the price will increase.

Other methods

There are other ways of chilling fish, e.g. blowing cold air over the fish, packing dry ice (solid CO_2) around the fish, or immersing in chilled water. Of these, chilling the fish in water (preferably sea water), cooled by mechanical means or by adding ice, is a suitable alternative means of chilling large quantities of small fish, particularly on board fishing boats. Other methods are far less satisfactory and/or too costly. Super chilling, or holding fish around −2°C, is not to be recommended and will be discussed in a later lecture.

Cold air. Passing refrigerated air over fish in a chill room is not an efficient method of chilling; heat from the fish will rapidly warm up the air surrounding the fish. The warmed air rises and is cooled as it reaches the coils of the evaporator and then falls, by natural convection or assisted by fans, back to the fish. It does not take very much heat to warm the air; 10 000 times as much heat is required to melt a given volume of crushed ice as to warm the same volume of air from 0 to 0.5°C. It is, however, possible to use the chill room in conjunction with ice to slow down the rate of melting of the ice. The ice must be allowed to melt; thus the temperature in the chill room should not be below say 4 to 5°C.

If fish are chilled with cold air, without ice, the fish will become dry; this is because the constant movement of air across the fish draws moisture from the fish and deposits it as frost on the coils of the evaporator. In addition, although the chill room is set to operate at say 0 to 1°C, the air close to the evaporator will be colder i.e. at below freezing temperatures. If fish are stacked high in the room, it is possible that they will become partially frozen.

Low temperature substances. There are a number of reasons why dry ice or liquid nitrogen is not used for chilling. Firstly, the temperature difference is so great, e.g. dry ice is at a temperature of −79°C, that the fish can become frozen so rapidly that damage is caused to the flesh. However, fish can be cooled indirectly by the cold vapour from dry ice or liquid nitrogen but, again, this is not satisfactory for the reasons outlined above. Secondly, these substances are extremely expensive since a lot of power is needed to make them. Another disadvantage is that they are not readily available. In some circumstances dry ice is used to keep already chilled fish cool. Liquid nitrogen and dry ice are, however, used for freezing fish.

Chilled and refrigerated sea water. These will be considered in the next session.

PROPERTIES OF ICE

You all know that water freezes at 0°C but you are possibly not familiar with the physical properties of ice and the technical terms involved which are important in understanding why ice is such a good cooling agent and in the principles of chilling.

A quantity of heat has to be removed from water to turn it into ice and the same amount has to be added to melt it. The heat required to change from a solid to a liquid is known as *latent heat;* 1 kg ice needs 80 kilocalories (kcal) heat to melt it. This figure of 80 kcal/kg is known as the *latent heat* of fusion. It is this property of requiring a lot of heat to melt ice that makes it such a good cooling agent.

1 kilocalorie (1 kcal) is the amount of heat required to raise the temperature of 1 kg H_2O by 1°C. More heat is required to warm water than almost any other substance. This capacity of substances to hold heat, when compared to water, is known as *specific heat.* The specific heat of water is 1, for other substances it is less than 1, e.g.:

ice	— about 0.5
wet fish	— about 0.96 (usually taken as 1)
frozen fish	— about 0.4
air	— about 0.25
most metals	— about 0.1

Specific heats can be used to discover how much heat has to be removed to cool a substance, e.g.

> Heat to be removed = weight of substance x temperature change x specific heat.
> To cool 60 kg ice from −5 to −10°C requires the removal of:
> $60 \times [-5 - (-10)]\,^{\circ}\mathrm{C} \times 0.5$ (sp. heat of ice) $= 60 \times 5 \times 0.5$ kcal
> $= 150$ kcal.

You can now calculate how much ice is theoretically needed to cool a given weight of fish

> If you want to cool 10 kg fish from 25 to 0°C, you need to remove $10 \times 25 \times 1$ (sp. heat of fish) = 250 kcal.
> But, when ice melts it absorbs 80 kcal.
> Thus the weight of ice required $= \frac{250}{80} = 3.12$ kg.

This is strictly a theoretical calculation; at the end of the cooling process there would be no ice left to keep the fish cool. It does not take into account the following factors:

- ice is also melted by the surrounding air, thus a lot of ice is lost, particularly at high ambient tropical temperatures unless the fish plus ice are protected from the outside heat, preferably with an insulating material
- how the fish are packed in ice
- length of time the fish need to be kept chilled
- how quickly the fish are chilled.

Although it is possible to calculate how much is required to chill the fish and keep them cool, the calculations are fairly complex and of course would not be carried out in practice. What is required is a rule-of-thumb guide. For initial chilling of the fish a ratio of at least 1 part ice: 1 part fish should be used. More ice should be added as required; sometimes fish will be completely re-iced at an appropriate stage in their handling. A successful icing regime is one in which, by the end of the voyage, journey or when required for further processing etc, the fish are chilled and there is still some ice present.

ICE MANUFACTURE AND STORAGE

Ice is made in block form, of various sizes and weights from 12 to 150 kg, or as 'small ice' a term used to describe many kinds of ice made in small pieces, i.e. flake, tube, plate, cube, ribbon etc. The different types of ice manufacturing plants are named after the type of ice which they produce; thus we have block ice plants, flake ice plants etc.

Before we look at how ice is made and stored, certain properties or features of manufactured ice, i.e. density, appearance, (whether it is clear or opaque), and the condition (whether it is wet or dry and subcooled) should be mentioned.

Density. The density or weight per unit volume of the various types of ice is different. Less space is required to store a tonne of block ice than a tonne of flake ice. Storage rates are as follows:

	m^3/tonne
Block ice, in blocks	1.4
Crushed block ice	1.4–1.5
Flake ice	2.2–2.3
Tube ice	1.6–2.0
Plate ice	1.7–1.8

Storage rates are important where space for storing the ice is limited, e.g. on board fishing vessels. In this case block ice or crushed ice would be preferred.

Appearance. Clear ice is produced by agitation during freezing and is generally preferred for the catering trade and for domestic use. It is considered to be more attractive. Block ice can be made either clear or opaque but flake ice is always opaque. For the fishing industry opaque ice is generally used; crushed ice may be used for display of fish in retail shops.

Condition. Dry subcooled ice is generally produced in icemakers that remove the ice mechanically from the cooling surface. Most flake ice plants produce dry subcooled ice. This must be stored below 0°C in order to keep it in a free-flowing form. Wet ice is usually made by plants that use a defrost procedure to release the ice, thus making the surface wet. Some of the wet ices can, however, be stored subcooled.

Manufacture

The main requirements in addition to the plant itself are water, power and also space.

Water. Ice must be made from water that is fit to drink. The amount of water required for making ice is roughly equal to the amount of ice produced. Air-cooled condensers can be used on small plants but, for larger plants, water-cooled condensers, often with a cooling tower, are more usual. Thus an additional supply of water is required for cooling. It is inadvisable to allow the cooling water to run to waste unless a plentiful supply is available.

Power. Power requirements vary widely depending on a number of factors, the most important of which are:

- type and size of plant
- operating temperature and air temperature
- temperature of ice make-up water and cooling water
- utilisation
- method of refrigeration

As an example, the power requirements for the icemaker and refrigeration machines for different types of plants under tropical and temperate conditions are given below

type of ice	*temperate area* (kWh/tonne)	*tropical area* (kWh/tonne)
flake	50–60	70–85
tube	40–50	55–70
block	40–50	55–70

Space. Block ice plants occupy a very large area in comparison with 'small ice' plants. In addition to the block icemaker itself, space is needed for the refrigeration machinery, ice store and for handling. With a flake ice plant, however, the icemaker is very compact and is usually sited on top of the store.

Common types of icemakers

Block ice (See Figure 1). Many years ago all commercial ice was manufactured in this type of plant. Nowadays, however, the automatic plants making small ice are becoming very popular.

Ice is made in rectangular cans or moulds which are immersed in a tank containing refrigerated brine. The plant can be designed to give freezing periods of 8 to 24 hours depending on the dimensions of the cans and the brine temperature. Block size can range from 12 to 150 kg.

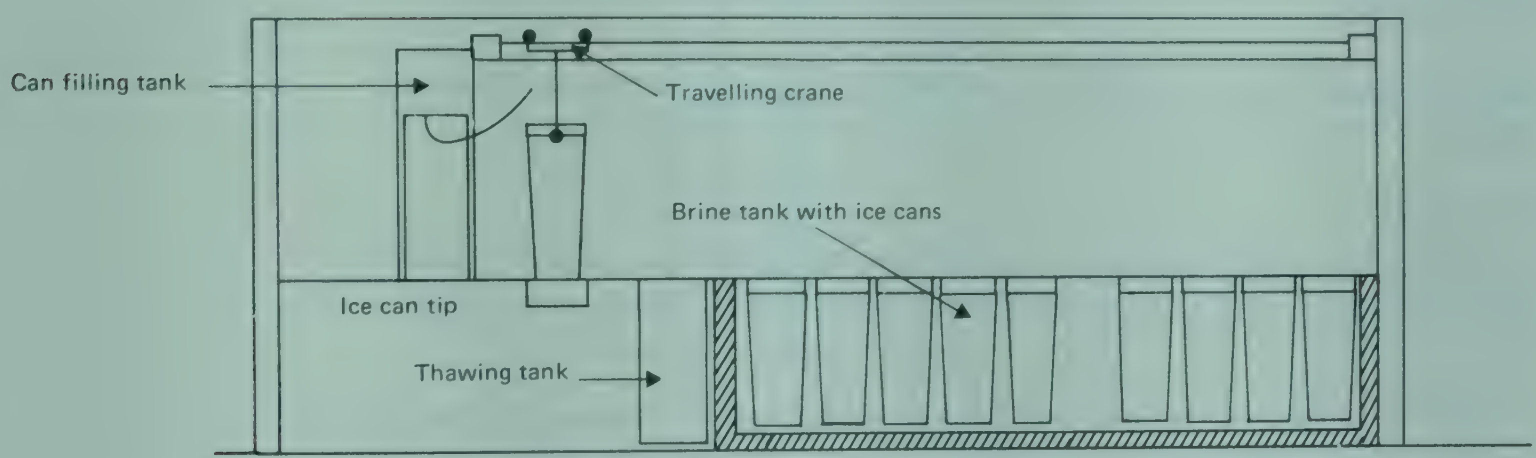
When the water has frozen, the cans are lifted (by a travelling crane) one row at a time and submerged in a thawing tank. They are then tipped and refilled with water. Harvesting or lifting can be a continuous or batch operation. Plant for batch harvesting is larger but labour charges are less.

Rapid block ice. In one type of plant the refrigerant passes through tubes around which the ice forms and fuses into a block. These blocks have a hollow core when the tubes are removed by defrosting. The space requirements for a rapid block ice plant are much less.

Flake ice (See Figure 2). A thin sheet of ice, 2–3 mm thick, is formed by spraying water on to a refrigerated drum; it is scraped off to form dry subcooled flakes. Water is not sprayed on to the surface immediately before the scraper. In some models the drum rotates; in others the scraper rotates; the drum is usually vertical.

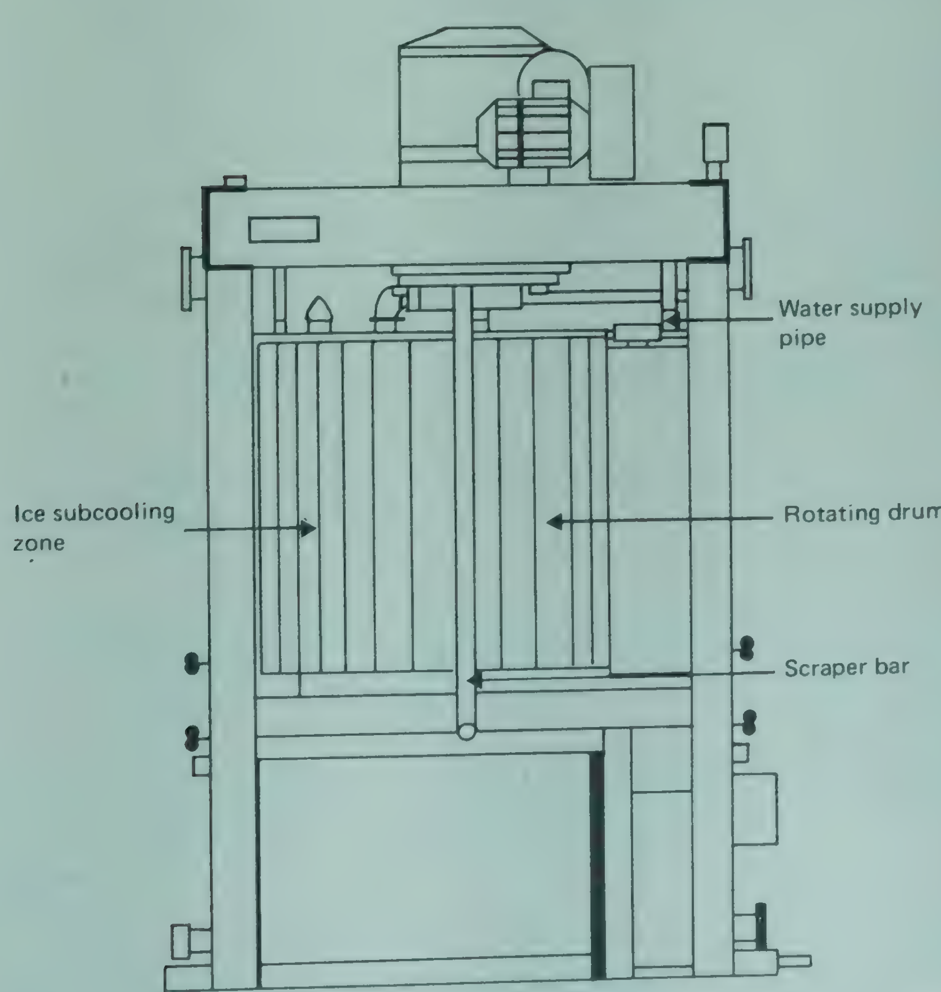
Flake ice production is automatic and continuous, the ice being stored in a refrigerated silo usually immediately below the icemaker. This type of ice is ready for use immediately it leaves the refrigerated surface.

Figure 1
Block ice maker



Source: Redrawn from Food and Agriculture Organization of the United Nations, Rome (1974) FAO Fisheries Report (59 revision 1).

Figure 2
Flake ice machine



Source: Redrawn from Torry Research Station (1975) Torry Advisory Note No 68.

Plate ice (See Figure 3). Plate ice is formed on one surface of a vertical plate and released by running water on the inside surface to defrost it. Multiple plates are arranged to form the icemaker. Plate ice plants are often self-contained units with the refrigeration equipment beneath the icemaker.

The thickness of the ice is 10–12 mm. An ice breaker is required to break the ice into suitable sizes for storage and use. Production is automatic.

Tube ice (See Figure 4). Ice is formed on the inner surface of a vertical tube as hollow cylinders 50 mm across with a wall thickness of 10–12 mm. The refrigerant surrounds the outer surface of the tube. The ice is released by a hot gas defrost process and as it drops from the tube it is cut usually into 50 mm lengths. The ice is then transported automatically to a store. This particle size is rather too large for fish and consequently an ice crusher is incorporated and, on discharge from the plant, the ice is crushed to suit the customers' requirements. The ice may not be subcooled when it reaches the store but, because of the size and shape of the 'tube', it is usually possible to maintain the store at –5°C. Thus tube ice can be wet or dry and subcooled.

Other icemakers: There are different systems in operation but mostly these are icemakers with capacities of up to a few hundred kilos only.

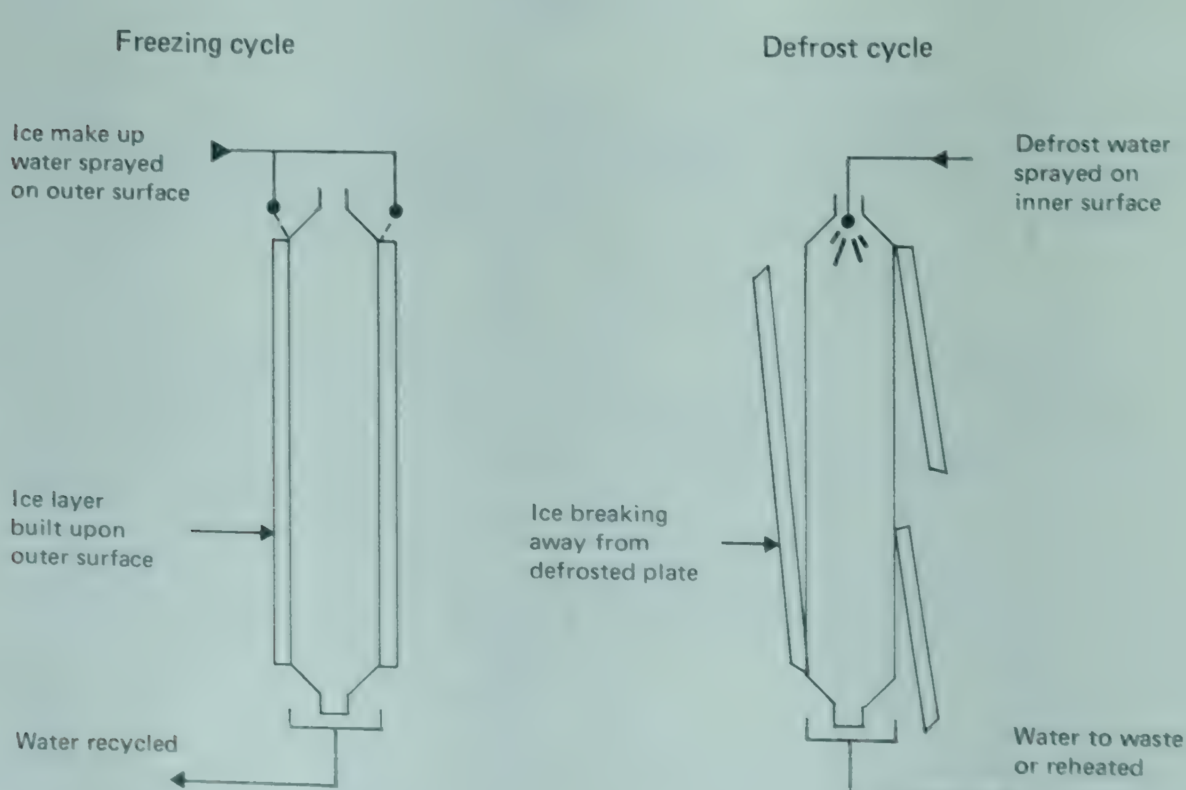
Sea-water ice

Sea-water ice is sometimes made on board factory vessels or on shore if water is extremely scarce. A few ice plants are designed for use with sea-water; others can be modified to make sea-water ice.

Sea-water ice has no advantages over freshwater ice; it has a number of disadvantages:

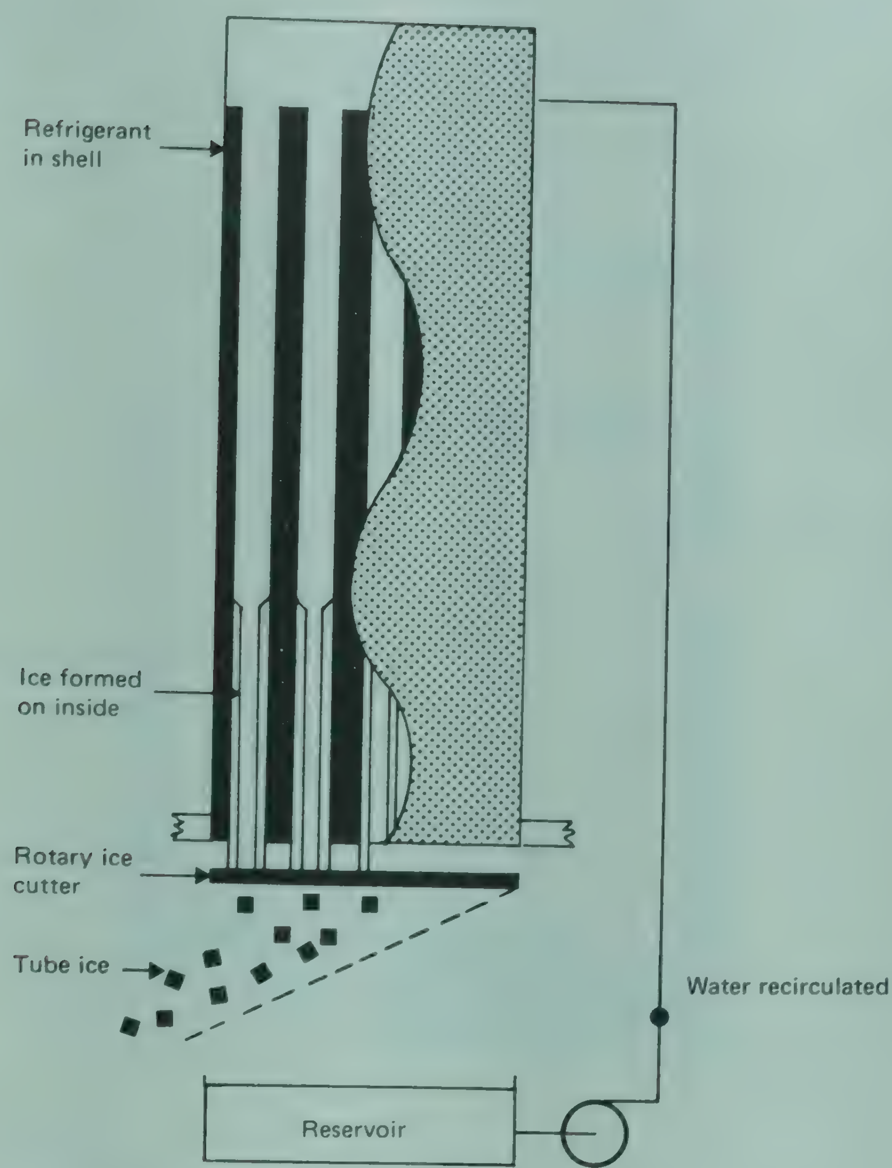
- at normal subcooling temperatures (–5 to –10°C) it will not be as flakes; lower temperatures are required for production and storage.
- the ice when made is generally not homogeneous and during storage the brine leaches out. Therefore it does not have a fixed melting point and fish may be at too low a temperature and become partially frozen.
- fish may take up some salt from the ice.

Figure 3
Plate ice maker



Source: Redrawn from Food and Agriculture Organization of the United Nations, Rome (1974) FAO Fisheries Report (59 revision 1).

Figure 4
Tube ice maker



Source: Redrawn from Food and Agriculture Organization of the United Nations, Rome (1974) FAO Fisheries Report (59 revision 1).

Storage

Since ice manufacture can seldom be managed to meet demand, storage is necessary to cater for peak demand and to allow the icemaker to operate 24 hours a day. It also acts as a 'buffer' against routine maintenance or possible breakdown.

The size of the store will depend on the pattern of operation and the type of ice but ice stores should be capable of holding at least 2 days' production.

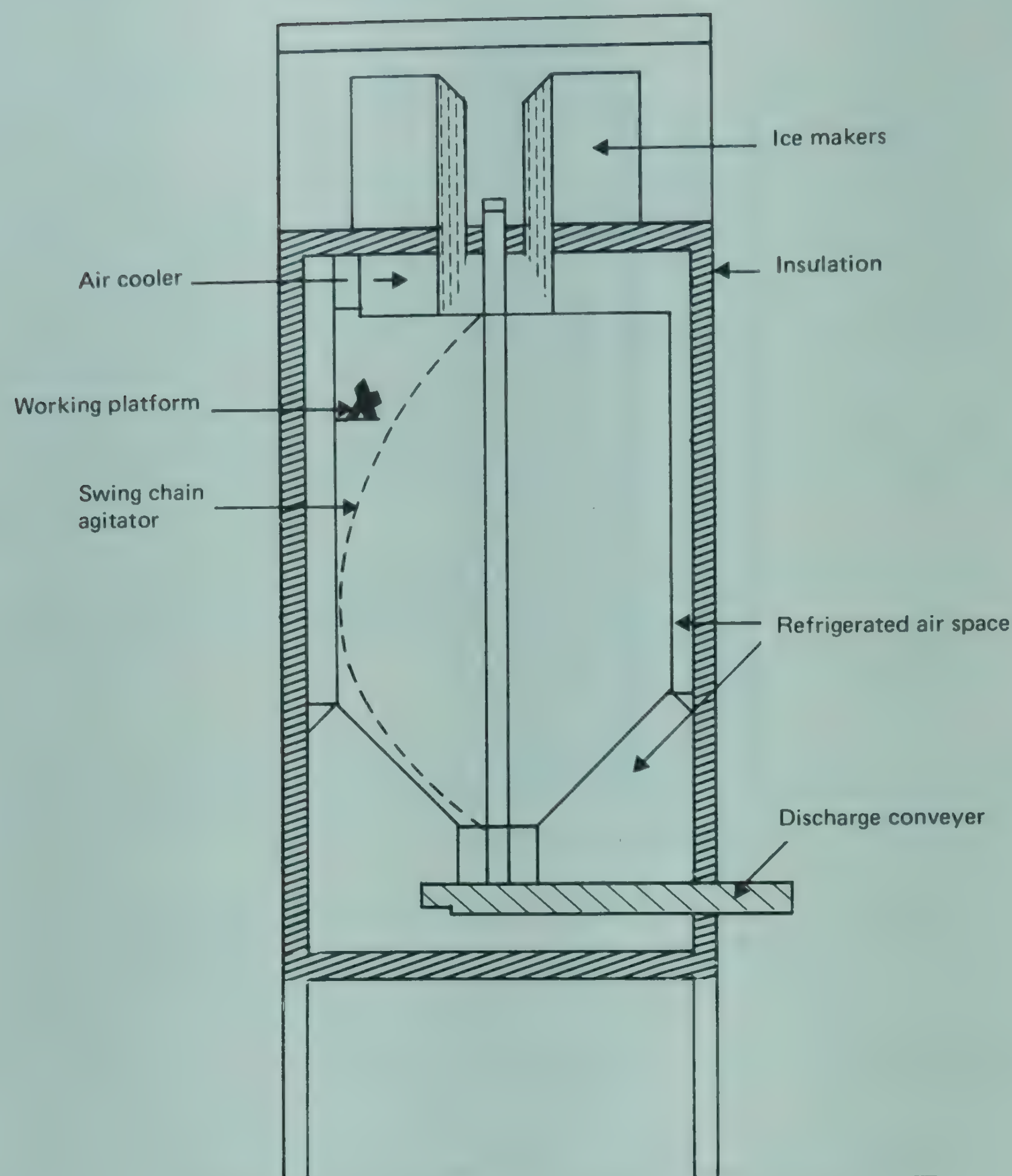
Ice stores can be simple insulated bins or large refrigerated silos or bins with automatic loading, unloading and weighing.

Silo storage. Silos are generally used only for storing free-flowing subcooled ice such as flake ice. They must have an independent refrigeration system. Silo storage is too expensive for small quantities. It is best suited for 40–100 tonnes. (See Figure 5.)

Ice is removed from the bottom of the silo, flow being assisted by an agitator. There should also be a device to scrape the ice from the walls of the silo which would otherwise build up with only the core remaining free-flowing.

Bin storage. Bins can be of any size from about a half a tonne to 1 000 tonnes or more and are used for storing fragmented ice. Refrigeration is not always essential but adequate insulation is essential.

Figure 5
Silo ice store



Source: Redrawn from Food and Agriculture Organization of the United Nations, Rome (1974) FAO Fisheries Report (59 revision 1).

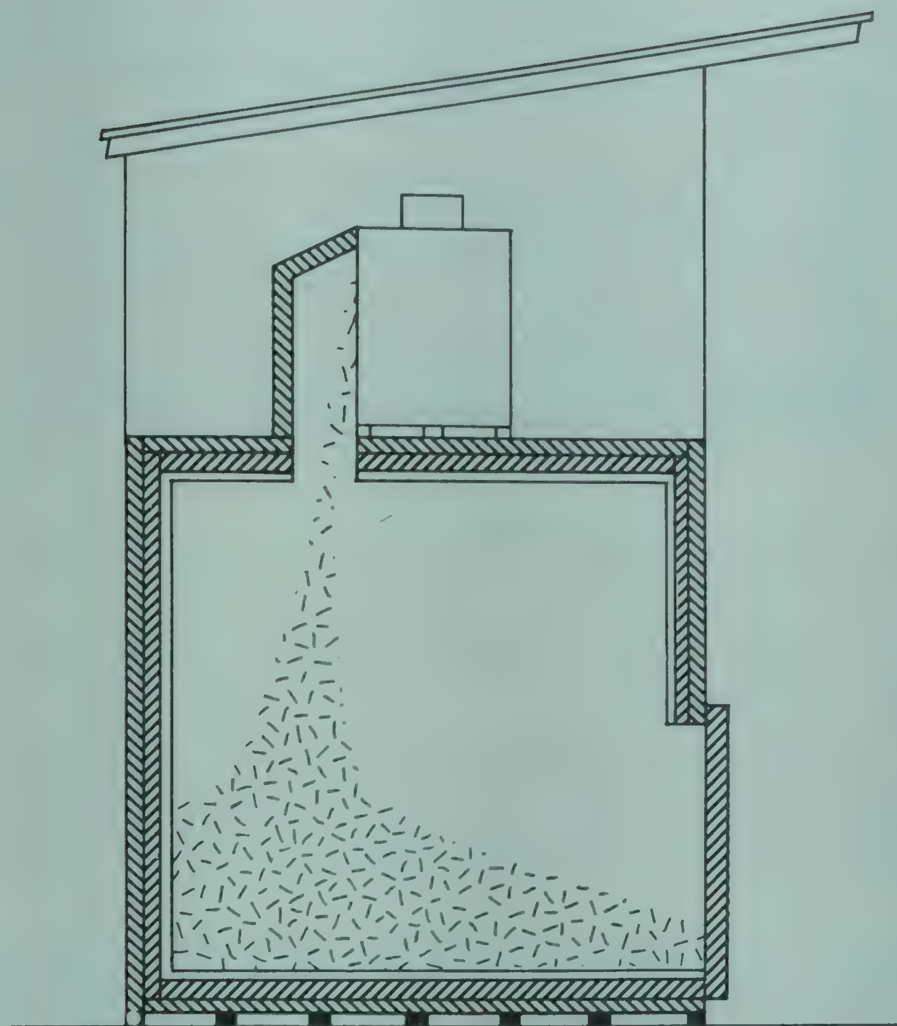
The bin could be a very simple box; for larger bins (see Figures 6 and 7) the ice plant can be mounted on top so that the bin is filled by gravity. The design of these bins must allow for:

- easy discharge of the ice
- older ice to be removed before the freshly made ice
- access for dislodging compacted ice.

Compacting is a problem that cannot always be solved by raking, shovelling or the use of moveable screw conveyors. It is therefore necessary to clear the bin periodically. The depth of ice in a bin must be limited to 5 m to avoid fusion of ice under pressure. For bins of more than 50 tonnes capacity a large floor area is necessary, the ice must be distributed evenly, and some form of mechanical harvesting, i.e. removing the ice from the bin is necessary. (See Figure 8.)

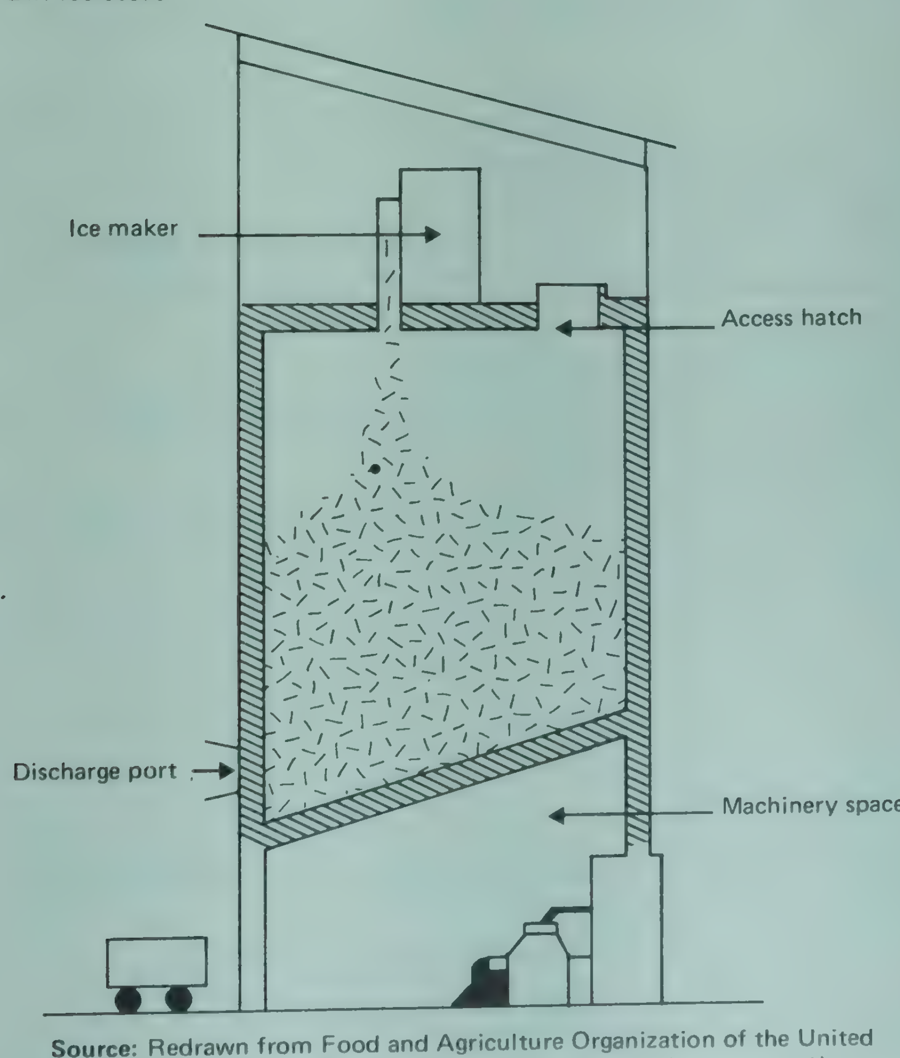
Block ice storage. Block ice is usually stored as blocks in a refrigerated room. Because of their shape and weight it is difficult to stack blocks; moreover, if the store is at below 0°C the blocks will freeze together, thus a large floor area is required.

Figure 6
Small ice store for 5–15 tonnes



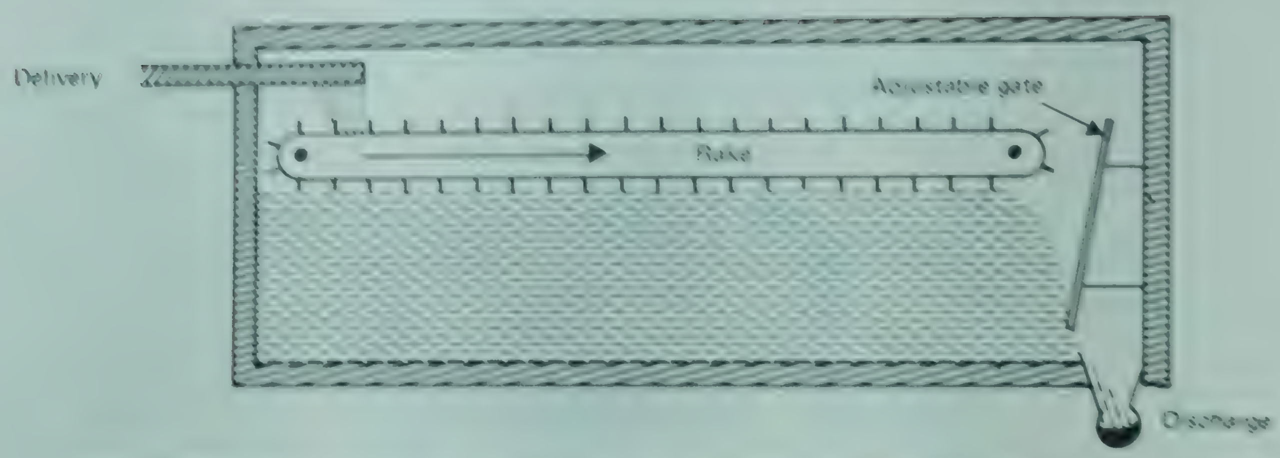
Source: Redrawn from Torry Research Station (1975) Torry Advisory Note No 68.

Figure 7
Bin ice store



Source: Redrawn from Food and Agriculture Organization of the United Nations, Rome (1974) FAO Fisheries Report (59 revision 1).

Figure 8
Large bin ice store with rake discharge system



Source: Redrawn from Food and Agricluture Organization of the United Nations, Rome (1974) FAO Fisheries Report (59 revision 1).

WHICH KIND OF ICE IS BEST?

Ice is ice: a given weight of any type of ice (but not volume) has the same cooling capacity. Also, the size of particles, within limits, makes little difference either to its rate of melting or to the speed of cooling the fish.

Since it is almost invariably used in small pieces it would seem sensible to manufacture the ice in the form in which it is to be used. However, this overlooks the problem of storage and transport. In certain fisheries, block ice may be the most suitable, in others a small ice such as flake ice is ideal. The differences, in terms of ice produced and ice plant, between flake ice and the other small ices are minimal in comparison with the differences between block ice and, say, flake ice. There is no simple answer as to which kind of ice is best. Factors which should be considered in assessing the merits of block ice and flake ice include:

Block ice

- Ice plant requires a lot of space and imposes heavy loads on the building
- Ice store also requires a lot of space
- Production of ice takes many hours
- Plant is labour-intensive; in the continuous 'harvest' system, blocks are lifted at regular intervals throughout the day and night, therefore shift work is necessary
- Plant is robust and simple to operate
- Ice must be handled or conveyed to the ice store, although ice can be used directly after harvesting (a gravity system cannot be used)
- Ice must be crushed before use
- Blocks are made to a specific weight and can be sold according to number
- Blocks melt less rapidly
- Large pieces of crushed ice can damage the fish and make poor contact with the fish

Flake ice

- Plant is very compact
- Plant is fully automatic
- Ice silo is usually sited below the icemaker and is filled by gravity
- Ice production is immediate
- Ice is dry and subcooled and must be stored below 0°C
- Ice is sold by weight or volume
- Ice is produced as flakes and is easy to use
- Ice makes excellent contact with the fish and cannot damage them

CONCLUSION

Time is so limited that this has been merely an introduction to the properties of ice, the different types of ice and the methods of manufacturing and storing ice.

Production of ice is an expensive process even if electricity, water and labour are comparatively cheap. Transportation costs will make the selling price even higher. Thus, the fishermen will only buy ice if they get a better price for better quality iced fish. In the next lecture you will hear about how to chill fish with ice.

Careful consideration must be given when deciding upon the type of ice plant and hence of ice for any fishery. The final choice will depend upon many factors including the utilities (or services) available, size of site, ambient temperatures, daily and annual requirements, cost of plant and operating costs etc.

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Chilling: applications and methods

We have already talked at some length about what chilling is and the different types of chilling media that can be used in the fishing industry. This session will deal with the way these media are used and outline suggestions as to how fish can be kept cool when the conventional cooling media are not available.

One of the most important chilling media used throughout the world in the fishing industry is ice. The advantages of ice over other means of chilling have already been dealt with; it is because of these advantages that it is used so widely.

STORAGE LIFE OF VARIOUS SPECIES OF FISH STORED IN ICE

Before we look at the actual use of ice, it is helpful to have an idea of the storage life that we can expect from our fish when we use ice. Storage life in this context means the length of time the fish can be kept in an edible condition with ice as the preservation medium. A considerable amount of experimental work has been carried out on the spoilage of temperate and cold-water species of marine fish of commercial importance in Europe and North America. Much of this has concentrated on a few species such as cod, haddock, hake, herring and mackerel. In the laboratory situation, ice storage trials are usually conducted under ideal conditions. These give an idea of the potential shelf life of the particular fish in question, using more ice than will probably be used commercially and holding the fish surrounded by ice throughout their storage period.

It is generally accepted that the storage life of cod in ice is in the region of 14 days. The table below gives the shelf life of various species of fish, both marine and freshwater and from tropical and temperate waters.

Fish	Length of storage in days
Temperate marine	
Cod	12–15
Haddock	12–15
Whiting	9–12
Hake	8–10
Herring	2–5 or 6
Mackerel	7–9
Red fish	13–15
Temperate freshwater	
Yellow walleye	20
White fish	18
Trout	10
Channel catfish	12

Tropical marine

Snapper (Brazil)	11–16
Red snapper (Seychelles)	20
Purple headed emperor (Bahrain)	15
Grouper	28
Spanish mackerel	11
Chub mackerel	18
Tuna	29
Bonga	20

Tropical freshwater

Tilapia	22–28
Mrigal carp	35
Catfish (Amazon)	12–16
Nile perch	20
Lung fish	25

The number and variety of different species encountered in the tropics precludes an intensive study of any one species and it was reported recently that workers throughout the world have studied the storage life in ice of more than 70 different tropical species. Unfortunately, most of the work is on a one-off basis with little confirmation of results and a great variety of different iced storage conditions. This situation makes direct comparison difficult and makes it almost impossible to come to firm conclusions in general terms about the spoilage of tropical fish in ice. However, it appears that:

1. Freshwater fish have a longer shelf life on ice than marine species;
2. Tropical species keep longer than temperate or cold-water species;
3. Non-fatty fish keep longer than fatty species.

There are no clear cut reasons as to why these differences might exist, although various theories have been put forward which are as follows:

1. Freshwater fish possibly contain in their flesh an antibacterial substance that is not found in marine fish and which inhibits the invasion of flesh by spoilage bacteria. In addition it seems that most freshwater fish also do not contain a substance called trimethylamine oxide (TMAO) which is present in marine fish. TMAO breaks down after death in marine fish into trimethylamine which produces ammonia-like odours and tastes. Freshwater fish do not produce ammonia-like odours during iced storage and may, therefore, be considered of better quality than marine fish after the same length of storage.

2. The apparent difference between tropical and cold-water species during iced storage is often explained by consideration of the normal temperature of the environment in which the fish live. The bacterial and enzymic systems of cold-water species are adapted to function most efficiently at lower temperatures than tropical species. When the fish and their bacterial flora are lowered to the temperature of melting ice (0°C) the temperature drop would be much greater with tropical fish than with those from temperate and cold-water. It has been suggested that this larger temperature drop could cause more of a shock to the enzymes and bacteria in tropical fish and explain the longer shelf lives found.

3. In general terms, the higher the fat content of fish flesh the softer and more delicate is the texture and structure of the fish. For this reason fatty fish tend to break down physically much more quickly than non-fatty fish during storage.

USING ICE AT SEA

The use of ice on board fishing vessels is common practice these days in many commercial fisheries where fishing voyages are of several days or more and fish must be kept in good condition until landing. In the small boat canoe-type fisheries in

many parts of the world it is not practical for ice to be taken to sea for a number of reasons. The main reason is that the vessel is too small to carry ice. It may also not be possible for the fishermen to recover the cost of ice through higher prices charged to the trader or consumer. Where the fisherman is at sea for only a short time, the application of ice immediately on capture of the fish may not be necessary.

The fish room

Commercial fishing vessels which store their catch on ice almost invariably have a hold below the working deck in which fish are stored. This hold is known as a fish room.

Fish rooms should be designed so that they are easy to clean and keep clean; all fitments must be strong and corrosion resistant and there must be adequate drainage from the fish room so that ice melt-water can drain away into what is known as the slush well. In order to make the best use of ice it is important that the fish room is well insulated. The fish room often has a bulkhead between it and the engine room and there are often large heat gains into the hold through this particular bulkhead. In tropical climates the warm seas and high ambient temperatures make adequate insulation particularly important. The amount of insulation is obviously variable, depending on the temperatures of the seas, the amount and length of fishing voyages and a number of other factors; these must be worked out in detail before any designs are put forward for a new fishing boat. We will be talking at a later stage about insulation regarding cold storage facilities and we will consider the insulation of the hold at that stage. Another important item which must be considered is the lining for the fish room which should ideally have the following characteristics:

1. It should be water-tight.

2. It should be hard and smooth-surfaced, so that it can be easily cleaned, and it should not contain cracks and crevices that will harbour dirt and bacteria.

3. It should be robust and able to withstand blows inflicted by ice axes, shovels and pound boards etc.

4. It should be light in colour.

5. It must not contaminate the fish.

6. It should not be corroded by fish oil, ammonia, brine etc.

7. It should be light in weight.

In addition to the insulation of the fish room, which acts as a barrier to heat penetration, it is recommended that, with all methods used to store fish, a layer of ice at least 15 cm thick be applied to the sides, bottom and bulkheads of the fish room as an additional barrier to heat gain. It is essential that no fish should be in direct contact with the fish room sides.

Stowage methods

There are three methods of storing fish in ice on fishing vessels.

1. **Bulking.** The fish room is divided into sections using pound boards supported by stanchions. The resultant pounds measure approximately 1.5 m^2 x 0.75 m high. A layer of ice at least 5 cm thick is spread over the bottom of the pound followed by a layer of fish. Ice is then spread over the fish and around the edges so that the fish are not in direct contact with the sides of the pound. Further layers of fish and ice are added until a depth of about 45 cm ice and fish is achieved with a layer of 5 cm of ice at the top. A horizontal pound board is now placed over the section. The pound board must be supported by the stanchion structures, not by the fish and ice in the lower compartment. More fish and ice are added in the same way again to a depth of about 45 cm. The operation is repeated until the pound is full. Pound boards and stanchions must be kept clean and out of direct contact with the fish.

2. **Shelving.** The fishroom is divided into sections as it is for bulking but this time removable shelves spaced at about 23 cm are used for holding the fish. The lowest shelf is covered with a layer of at least 5 cm of ice. Fish are placed in rows on the ice and more ice is used to cover the fish to about 5 cm. Only one layer of fish is to be put on to each shelf. Shelves must be supported by stanchions, not by the fish and ice below.

3. **Boxing.** Fish boxes come in a variety of sizes and materials. Ideally, a box should be:

(1) Strong and robust.

(2) Able to be stacked so that the weight of the top boxes are taken by the boxes below, *not* by the fish in the box below.

(3) Able to nest to save on stowage space when empty.

(4) Easily cleaned and if necessary sterilised.

(5) It should allow ice melt-water to flow away outside the box below, not through, the fish in the box below.

(6) It should have good thermal insulation.

There are a number of designs and sizes of fish boxes made in plastics and aluminium which fulfil many of the above requirements and, furthermore, are light and easy to handle. As yet, however, no manufacturer has designed a box which will stack (point 2), nest (point 3) and allow the ice melt-water to flow away outside the box (point 5). These plastic and aluminium boxes are replacing the older styles of wooden boxes which tend to be difficult to keep clean and do not last as long.

Fish boxes should be used as follows:

A layer of ice 5 cm thick should be placed in the bottom of the box followed by a layer of fish. A thin layer of ice follows, interlacing fish and ice, until the box is almost full. The ice should be placed around the sides of the box as well as amongst the fish and the top layer of fish should be covered with at least 5 cm of ice. The box must not be overfilled. This prevents crushing the fish when the boxes are stacked into the fish room. When boxing fish, the fish room has no internal pounds or stanchions as in the bulking and shelving methods. There may however be restraining bars and straps to prevent stacks of fish boxes falling over.

Bulking, shelving or boxing?

There are various factors to be borne in mind when choosing which method of stowage of fish at sea to use.

Bulking

1. Of the three methods bulking is the most economical on space.

2. Fish can be subjected to physical damage through pressure of fish above and pressure of lumps of ice.

3. In general bulked fish will be of poorer quality than shelved or boxed fish after the same length of time.

4. Mixing of different catches and 'ages' of fish during bulking can be a problem.

5. Fish are often subjected to rough handling during stowage and discharge.

Shelving

1. Of the three methods shelving is usually the least economical on space.

2. Fish are not subjected to physical damage.

3. If well iced on top, fish are of better or at least equal quality to bulked fish.

4. Method is very labour intensive.

5. Fish can be separated easily into different catches.

Boxing

1. Boxing is intermediate between shelving and bulking in terms of space requirements.

2. Fish can be separated into size, species and age and kept separate throughout distribution.

3. Handling is kept to a minimum.

4. With good boxing practice fish will not be damaged physically.

Refrigerated fish rooms

Some fish rooms not only have insulation but also have refrigeration facilities. This refrigeration is usually in the form of cooled grids and pipes on the roof of the fish room. It is important to get the maximum cooling effect from ice that is allowed to melt. For this reason the temperature in the fish room should not fall below 0°C. In order to prevent melting of ice, it is common practice for refrigeration to be used only when the vessel is carrying ice alone before fishing starts. Under these circumstances the temperature can be below 0°C.

Insulated boxes

In an increasing number of small boat fisheries insulated boxes are used to carry ice to sea, and for storing ice and fish, when fishing occupies only a short period. The size of the boxes depends on the size of the boat and the amount of fish normally caught in a day's fishing. The ambient temperature will govern the amount of insulation required in the box, though about 10–15 cm of expanded polystyrene is common. Insulated boxes for small fishing boats can often be made locally at small cost.

SUPER CHILLING

Super chilling means reducing the temperature of fish uniformly to a point slightly below that of melting ice. The temperature is that at which half the water present in the fish is frozen. This is approximately –2.2°C. At this temperature, the size of ice crystals formed in the fish is such that the texture is not affected and the shelf life is extended because of the effect on bacteria of a slightly lower temperature.

Super chilling is sometimes used on board fishing vessels but not normally on shore: it thus enables the vessels to extend the length of their journey in comparison with icing vessels. The methods of super chilling involve initially chilling the fish with ice as has already been described and then refrigerating the fish room to the desired temperature, by using cold air or by circulating refrigerated brine through the fish room walls. Because of difficulties of maintaining the temperature at the correct level super chilling is not widely used and is not recommended in most situations. Super chilling extends the shelf life of cod for instance from about 15 days on ice to 20–25 days under super chill conditions.

CHILLED AND REFRIGERATED SEA WATER (CSW AND RSW)

The fishing methods employed for catching pelagic fish such as mackerel, herring, sardine etc., often involve large quantities of small fish being landed at the same time and in a fairly short period. To ice these fish efficiently would be a long and tedious operation and it is much easier to submerge them in a cooled liquid to bring their temperature down.

Sea water is the liquid used on purse seining vessels where these problems may occur and sea water is either chilled using ice (CSW) or mechanical refrigeration (RSW).

The vessels have fixed or moveable sea water tanks depending on their size. A series of pumps, strainers and valves circulates the water, cooled either by ice or mechanical refrigeration, through the tanks.

The advantages of CSW and RSW over ice in this situation are as follows:

1. Cooling is more rapid.

2. It is easier to load fish into the tanks. Fish are not squashed or crushed during stowage.

3. Fish are washed and bled in the tank.

On the other hand, the reason that sea water stowage is not used more generally is that fish tend to absorb unacceptable quantities of salt and the storage life in sea water of some species is shorter than in ice.

KEEPING FISH COOL

In many situations the small boat fisherman does not have access to ice or to chilled refrigerated storage conditions. There are, however, a number of ways that he can keep his fish cooler and so extend its shelf life by a few hours at least. These do not chill the fish but lower temperature by a few degrees.

1. Fish should always be kept in the shade. Shade temperatures are almost invariably lower than sun temperatures.

2. Keeping the surface of the fish wet will help to bring its temperature down. This is because the moisture evaporates from the surface and absorbs heat from the fish as it does so. It is easier to keep the fish damp if some material, such as wet seaweed, damp sacking, or damp sawdust, is used to absorb some of the moisture and prevent it running away. When carrying non-iced fish on vehicles it is advisable to make sure the fish are kept damp and that air can circulate over the fish and thence keep it cool. It must be remembered, however, that the dampness will evaporate relatively quickly under warm conditions and it may be necessary to re-wet the fish at a later stage of transportation.

3. Where practicable, it is advisable to keep the fish in the water until landing or until it is necessary to take them on board the boat. In this way they will be kept at a lower temperature since water temperatures are usually lower than ambient air temperatures.

Freezing: theory and definitions

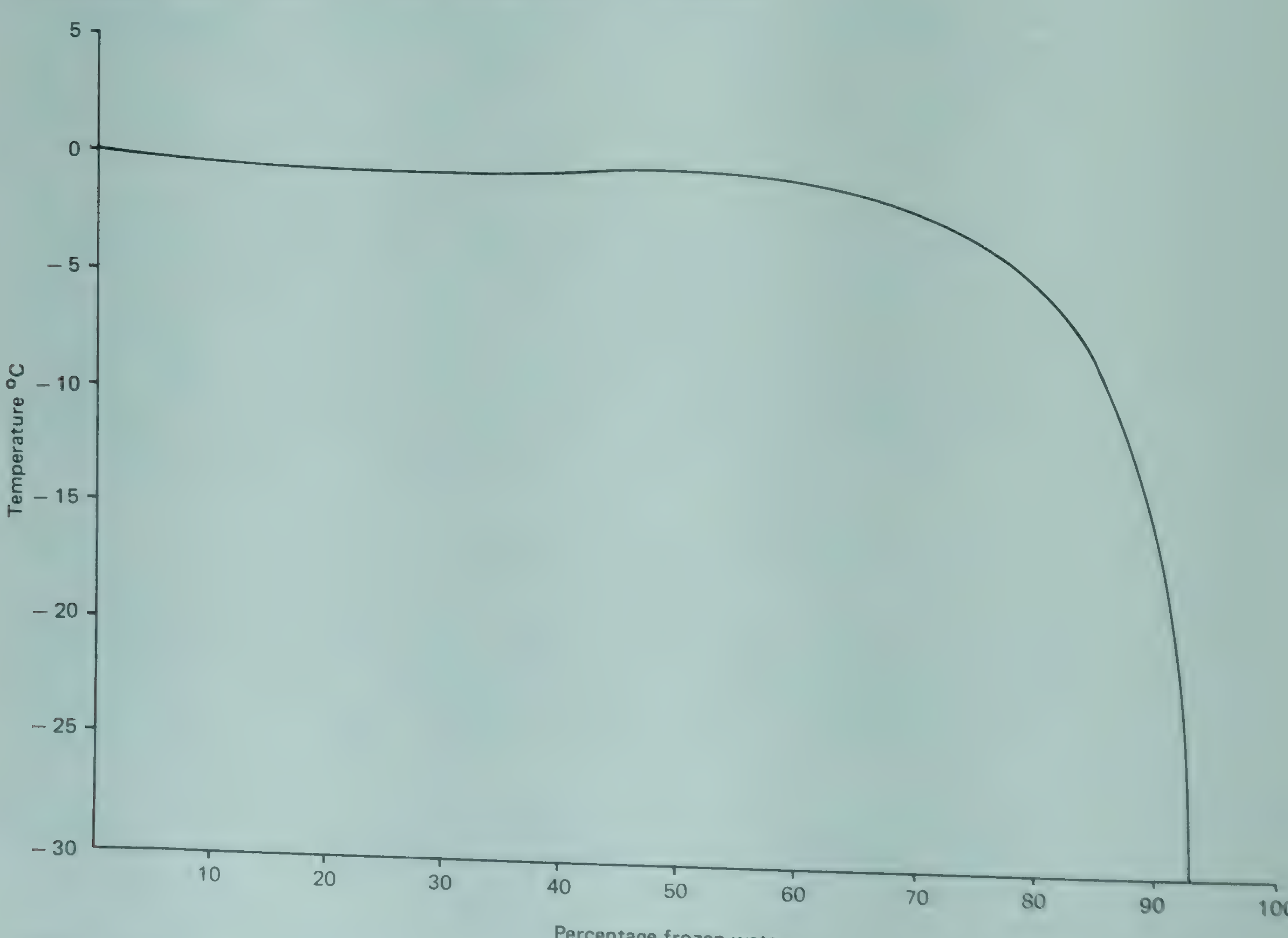
We have seen that by using ice and other chilling techniques we can keep fish in a 'fresh' condition for anything from a few days up to four weeks or so depending on the species of the fish. In many situations it is desirable to be able to keep the fish fresh longer than a few weeks, for instance for export to distant countries, to even out supplies because of seasonal variations in catch and when fishing grounds are a long way from port. It is not possible to keep the fish fresh for prolonged periods but it is possible to produce a product which closely resembles fresh fish by using freezing and cold storage.

WHAT IS FREEZING OF FISH?

Fresh fish flesh contains approximately 80 per cent water. At normal atmospheric pressure pure water will change from a liquid to a solid (ice) at 0°C. i.e. it will freeze.

Figure 9

Percentage of water frozen at different temperatures in fish muscle



Source: Redrawn from Food and Agriculture Organization of the United Nations, Rome (1977) FAO Fisheries Technical Paper (167).

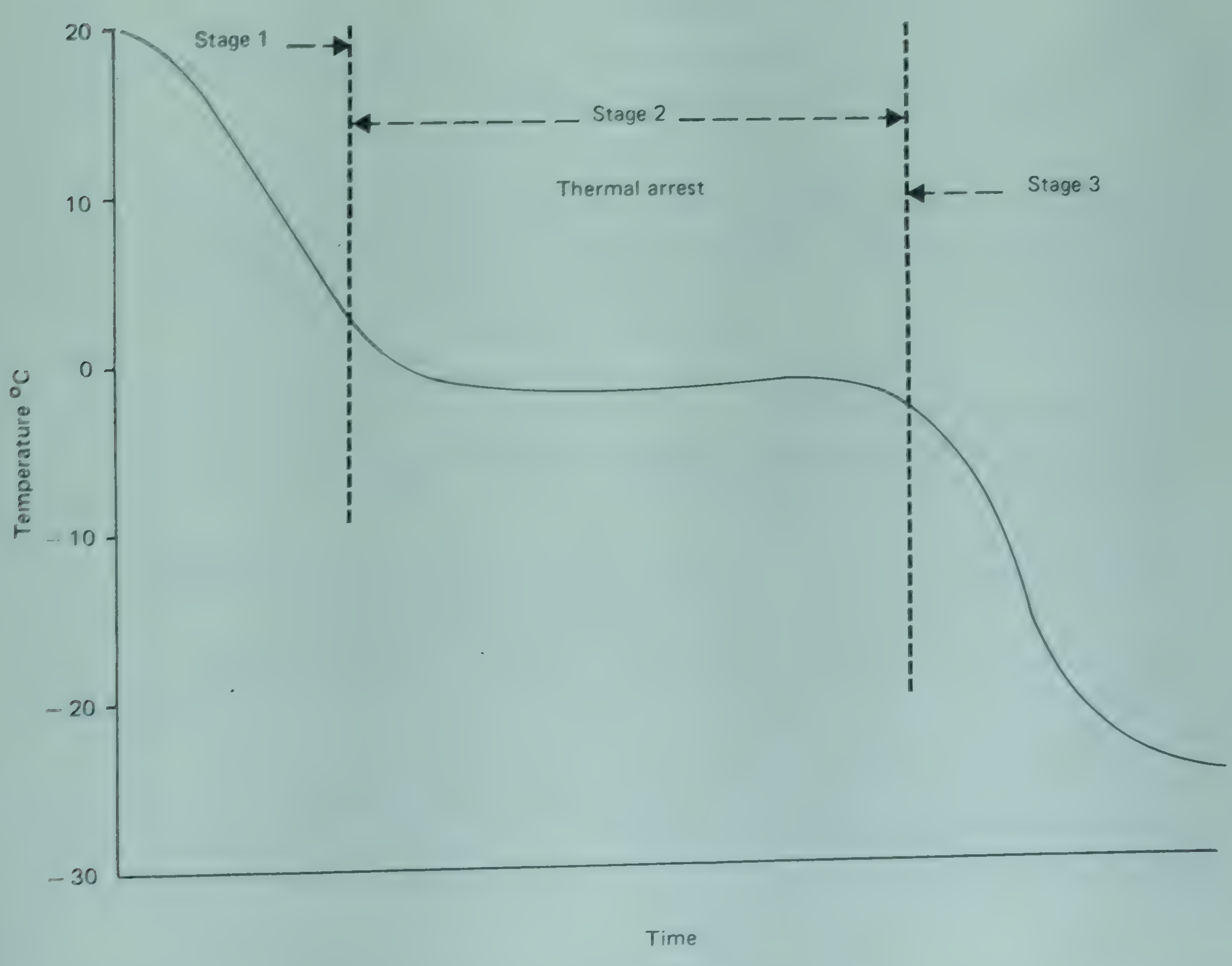
The water in fish flesh contains salts and chemicals which have the effect of lowering the temperature at which the water begins to freeze. The water in fish flesh begins to freeze at about −1°C, and as the temperature drops below −1°C, more water is frozen out and the concentration of salts in the remaining water rises so that its freezing point is lowered further. At −5°C, when it would appear that all the water is frozen, over 20 per cent of the water in fish muscle is still unfrozen. Even at −30°C approximately 10 per cent of the water remains unfrozen. (See Figure 9).

In order to change the physical state of a substance from a liquid to a solid, as we are doing when we are freezing fish, energy or latent heat has to be removed from the substance. In order to lower the temperature of 1g of water by 1°C, at temperatures above 0°C, 1 calorie of heat must be removed, this is known as the specific heat. However, to change water at 0°C to ice at 0°C, 80 calories must be removed for each g of water.

Thus the specific heat of liquid water is 1 and the latent heat required to change liquid water to ice is 80. The specific heat of ice at temperatures below 0°C is 0.5 which means that to lower the temperature of 1 g of ice by 1°C we would need to remove 0.5 calories of heat. For all practical purposes it is assumed that fish have the same values for specific heat and latent heat as water.

All this means that if we remove heat from fish at a constant rate there will be a period whilst the fish is freezing when the temperature of the fish will not drop. This period lasts until approximately 75 per cent of the water is frozen, when the temperature begins to drop again. There are then three stages to freezing fish. In

Figure 10
Typical fish freezing curve



Note: Under ideal conditions fish would be frozen to −30°C in 3 hours

Source: Adapted from Food and Agriculture Organization of the United Nations, Rome (1977) FAO Fisheries Technical Paper (167).

stage 1 the temperature falls fairly rapidly to just below 0°C, during stage 2 the temperature remains fairly constant at about −1°C as the bulk of the water in the fish freezes; this stage is known as the 'thermal arrest' period and during stage 3 the temperature again drops and most of the remaining water becomes frozen. This 3-stage reduction in temperature during freezing is illustrated in Figure 10.

Using simple mathematics we can calculate the amount of energy required to freeze fish. This is most easily demonstrated by making a simple calculation as follows:

> Suppose we have 1 kg of fish at 25°C and we wish to freeze it to −30°C. During stage 1 we need to extract 1 calorie of energy for each g of material for each drop of 1°C. In the example we will be lowering the temperature of 1 000 g of fish from 25°C to −1°C, i.e. by 26°C. The energy required will be equal to 1 000 x 26 x the specific heat of water (1) = 26 000 calories or 26 kilocalories.
>
> During stage 2 we need to extract 80 calories of energy for each g of material frozen. In the example 1 000 g of fish are to be frozen. The energy required will be equal to 1 000 x the latent heat for freezing water (80) which equals 80 000 calories or 80 kilocalories.
>
> During stage 3 we need to extract 0.5 calories of energy for each g of material for each 1°C drop in temperature. In the example we will be lowering the temperature of 1 000 g fish from −1°C to −30°C, i.e. by 29°C. The energy required will be equal to 1 000 x 29 x the specific heat of ice (0.5) = 14 500 calories = 14.5 kilocalories.

To summarise:

Stage 1	1 000 x 26 x 1 = 26 kilocalories
Stage 2	1 000 x 80 = 80 kilocalories
Stage 3	1 000 x 29 x 0.5 = 14.5 kilocalories

Adding these three figures gives us 120.5 kilocalories, i.e. to freeze 1 kg of fish from 25°C to −30°C we require 120.5 kilocalories of energy.

From the example above it is apparent that more than 50 per cent of the energy extraction during freezing of fish is necessary during stage 2, the thermal arrest period when little or no drop in temperature is occurring, and this period is a critical one if we are to produce a good frozen product. Ideally, fish should pass through the thermal arrest period as quickly as possible.

There are various reasons for this:

1. Slow freezing produces large ice crystals in the cells of the fish which can be larger than the cells themselves and so break the cell walls.
2. We have already mentioned that, as the water begins to freeze in the flesh, the concentration of salts and chemicals in the remaining water rises. This high concentration of salts and enzymes can cause accelerated autolysis.
3. At temperatures around 0°C, certain types of bacteria are still active and bacterial spoilage can still occur.

Textural changes occur in fish that have been frozen slowly caused by the presence of large ice crystals and denaturation of protein during the accelerated autolysis. In addition a phenomenon known as 'thaw drip' occurs when slowly frozen fish are thawed. On thawing, the water which was originally bound within the cells is released and considerable loss in weight can occur.

However, from a textural point of view it is unlikely that a highly trained taste panel could detect the difference between fish frozen in one hour and those frozen in eight hours but, once freezing times extend beyond 12 hours, the difference may well become apparent. Freezing times of 24 hours or more will almost certainly

result in an inferior product and very long freezing times can result in bacterial spoilage making the fish unfit for consumption.

FREEZING DEFINITIONS

What is quick freezing?

There is no widely accepted definition of quick freezing.

In the United Kingdom quick freezing is defined normally as lowering the temperature of fish from 0°C to –5°C in 2 hours or less and further reducing the temperature at the end of the freezing period to the recommended storage temperature of –30°C. These two basic requirements for freezing, that the fish should be frozen quickly and then reduced to storage temperature, go together since it is likely that a freezer which can quick freeze fish also operates at sufficiently low temperatures to ensure that the recommended product storage temperature can be achieved. The recommendation that the fish should be reduced to the intended storage temperature is important and this should be included in all good codes of practice for quick freezing.

Freezing rates

Some freezing codes and recommendations define freezing rate in terms of the thickness of fish frozen in unit time. The freezing rate, however, is always faster near the surface of the fish, where it is in contact with the cooling medium, and slower in the centre. Freezing rates therefore are only average rates and do not represent what happens in practice. The table below gives an idea of the terms used in relation to freezing at different rates.

Term used	*Rate of freezing*
Slow freezing	2 mm/hour
Quick freezing	5–30 mm/hour
Rapid freezing	50–100 mm/hour
Ultra rapid freezing	100–1,000 mm/hour

'Sharp' freezing is a term that is often used when people talk of freezing fish but the term has no precise definition and in practice sharp freezing is often very slow.

'Deep' freezing is defined by the International Institute of Refrigeration as a process whereby the average temperature of the product is reduced to 0°F (–17.8°C) and then kept at 0°F or lower. The definition does not take into account the rate of freezing and a product that has been deep frozen may not necessarily have been quick frozen before storage.

One exception to the general requirements for quick freezing of fish is frozen tuna. The Japanese product 'Shasimi' is based on eating raw tuna. Tuna can be very large fish (up to 60 or 100 kg) and the Japanese market requires whole fish. Japanese fishing vessels catching fish for Shasimi operate air blast freezers at –50 to –60°C air temperature. This very low air temperature in the blast freezer overcomes, to some extent, the very poor heat extraction from the centre of such large fish. Even with temperatures of –50 to –60°C it still takes 24 hours to freeze tuna at the centre. The above requirements for air blast freezing tuna are one special case where general rules for quick freezing are not applied and it should be kept in mind that local requirements for particular products may, in some countries, give rise to others.

DOUBLE FREEZING

'Double freezing' means freezing a product, thawing, or partly thawing it, and re-freezing. This practice is often necessary for production of some frozen fish

products made from fish previously frozen and stored in bulk. What must be remembered is that even quick freezing results in quality changes in the fish and double freezing will therefore result in further changes. Only fish that were initially very fresh could therefore be subjected to double freezing and still conform to goods quality standards. Fish frozen quickly at sea immediately after catching, for instance, would be suitable for this purpose.

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Freezing: applications and methods

There are three methods of freezing fish:

1. Blowing a continuous stream of cold air over the fish: air blast freezing.
2. Direct contact between fish and a refrigerated surface: contact or plate freezing.
3. Immersion in, or spraying with, a refrigerated liquid or refrigerant: immersion or spray freezing.

Since there are nowadays a number of different freezers employing these three principles, it is often difficult to know which type is most suited to your needs. We will therefore look at some of the freezers currently available and how they are used. Cost considerations and other factors influencing the final choice cannot be dealt with here.

AIR BLAST FREEZERS

The main advantage of blast freezers is their versatility. Their disadvantages however are that they occupy a lot of space and consume more power than equivalent plate freezers. Also because of their versatility they are frequently used incorrectly or inefficiently.

There are two main types of air blast freezers:

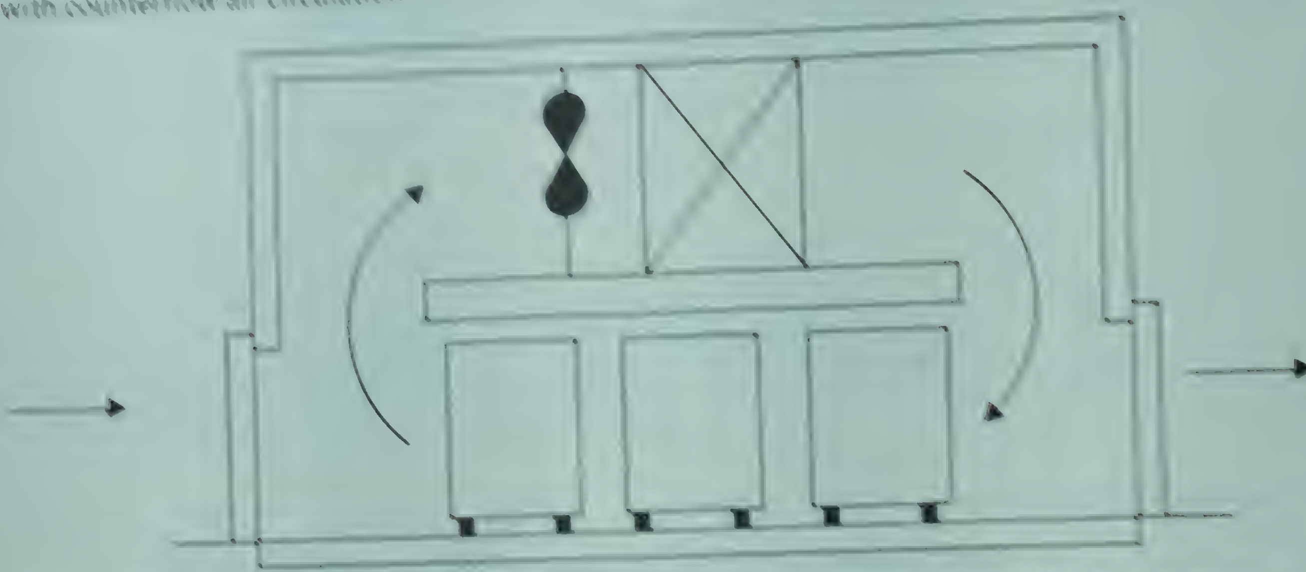
1. Continuous: in which the product moves through the freezer.
2. Batch: in which the product is stationary.

Uniform freezing is achieved only if the temperature and speed of the air over the product are constant; fairly high air speeds are required to avoid excessively long freezing times. These high air speeds are produced by powerful fans which tend to heat the air and this excess heat must be removed by the refrigeration machinery. An air speed of 5 m/s is recommended for most air blast freezers; this is a compromise between slow freezing rates and high fan costs. For continuous air blast freezers, higher air speeds of 10 to 15 m/s may be justified; freezing times are reduced and a smaller freezer will be needed for a given freezing capacity, thus saving on freezer costs.

Continuous air blast freezers

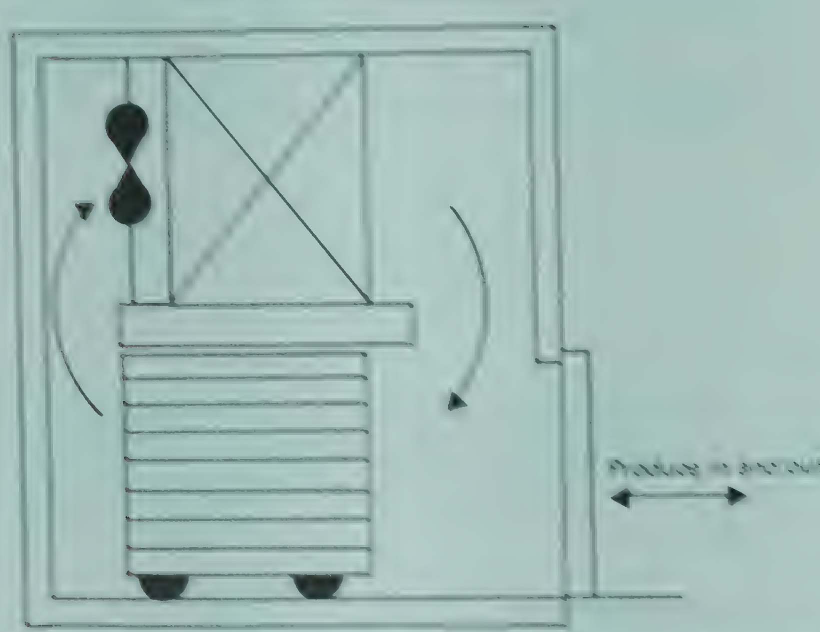
In one system, fish are loaded on trucks or trolleys which are moved through the freezer on rails (this is known as batch-continuous operation); in the other system, fish are carried through the freezer on a moving belt or conveyor. Continuous air blast freezers are most suitable for freezing similar-shaped products with similar freezing times.

Figure 11
Batch-continuous air blast freezer
with counterflow air circulation



Source: Redrawn from Food and Agriculture Organization of the United Nations, Rome (1977) FAO Fisheries
Technical Paper (167).

Figure 12
Batch-continuous air blast freezer
with crossflow air circulation



Source: Redrawn from Food and Agriculture Organization of the United
Nations, Rome (1977) FAO Fisheries Technical Paper (167).

Batch-continuous: Figure 11 shows a typical arrangement for a batch-continuous air blast freezer with counterflow air circulation. The flow of air must be in the opposite direction to the movement of trucks, ie the coldest air flows over the coldest fish.

Fish are generally packed in trays and loaded on to a trolley. When the trolley is fully loaded, it is pushed into the freezer. As further trolleys are loaded, these are pushed in, thus, as the freezer is filled it is necessary to push a row of trolleys forward. This can be a difficult task because at low freezing temperatures the rails readily become frosted up and, unless special bearings are fitted to the wheels and the correct lubricants used, the wheels will not turn. When the freezer is full, no more trucks can be pushed in until the first truck-load has been completely frozen. In batch-continuous freezing it is necessary to switch off the fan during loading and unloading.

Batch-continuous air blast freezers are also designed with crossflow air circulation i.e. the air flows across the product as shown in Figure 12. In this system there may be several fans and more than one cooler unit. If the freezer has a series of doors

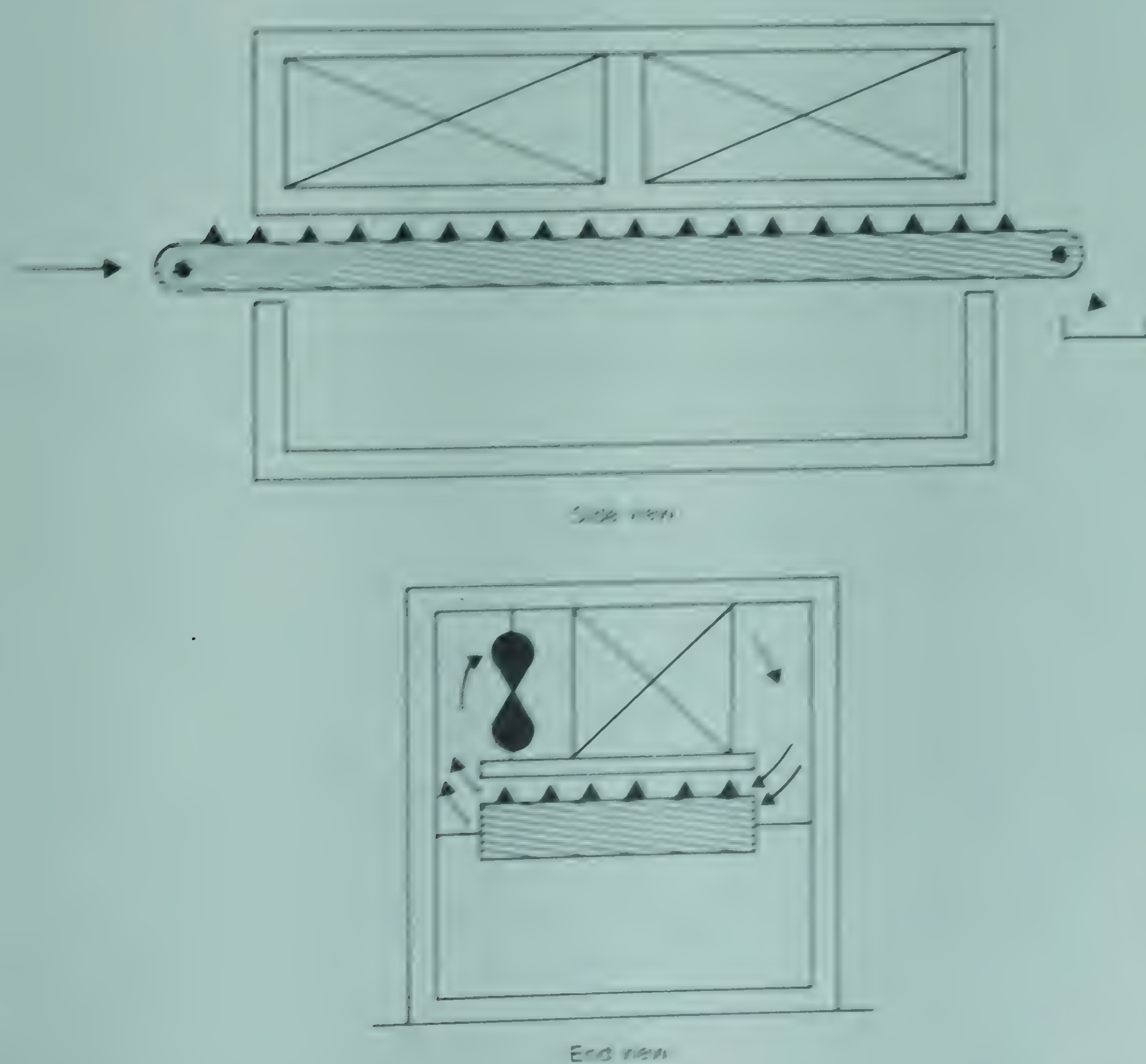
along the side, single trucks can be loaded without the need to move a whole row. Once the freezer is full, no more trucks can be added until the freezing cycle of each truck load is completed.

Continuous belt or conveyor. This system can be used only if the product can freeze quickly, i.e. in less than 30 minutes, otherwise the freezer would be too long and cumbersome. Freezing time, freezing requirements and load density determine the length of the belt. If double and triple belts are used, the space needed for the freezer can be reduced but these are suitable only for products which can easily transfer from one belt to another e.g. 'battered' and 'breaded' products. Spiral belt freezers which are used for individually quick frozen (IQF) products also require less space.

The belt must be flexible, easily cleaned, non-corrosive, non-toxic to food and should not affect the freezing time or the quality of the product. It is usually made of stainless steel mesh links or chain links. These are, however, expensive and give the product a crinkled appearance, and it can be difficult to remove the frozen fish. An alternative type of belt is made of plastic interlocking links but this also has certain disadvantages (it adds 10 per cent to freezing time and has a rather open mesh).

Continuous belt freezers are designed with either crossflow (see Figure 13) or counterflow air circulation. The points of entry and exit of the belt must be protected against infiltration of warm air.

Figure 13
Continuous belt air blast freezer with crossflow air circulation



Source: Redrawn from Food and Agriculture Organization of the United Nations, Rome (1977) FAO Fisheries Technical Paper (167).

To keep freezing costs down, continuous freezers must be fully loaded. In a continuous freezer the belt speed is usually variable and can be adjusted to accommodate different product freezing times but, once it has been adjusted for a particular product, it must be used only for that product. Thus the capacity can be altered depending on the product and its freezing time.

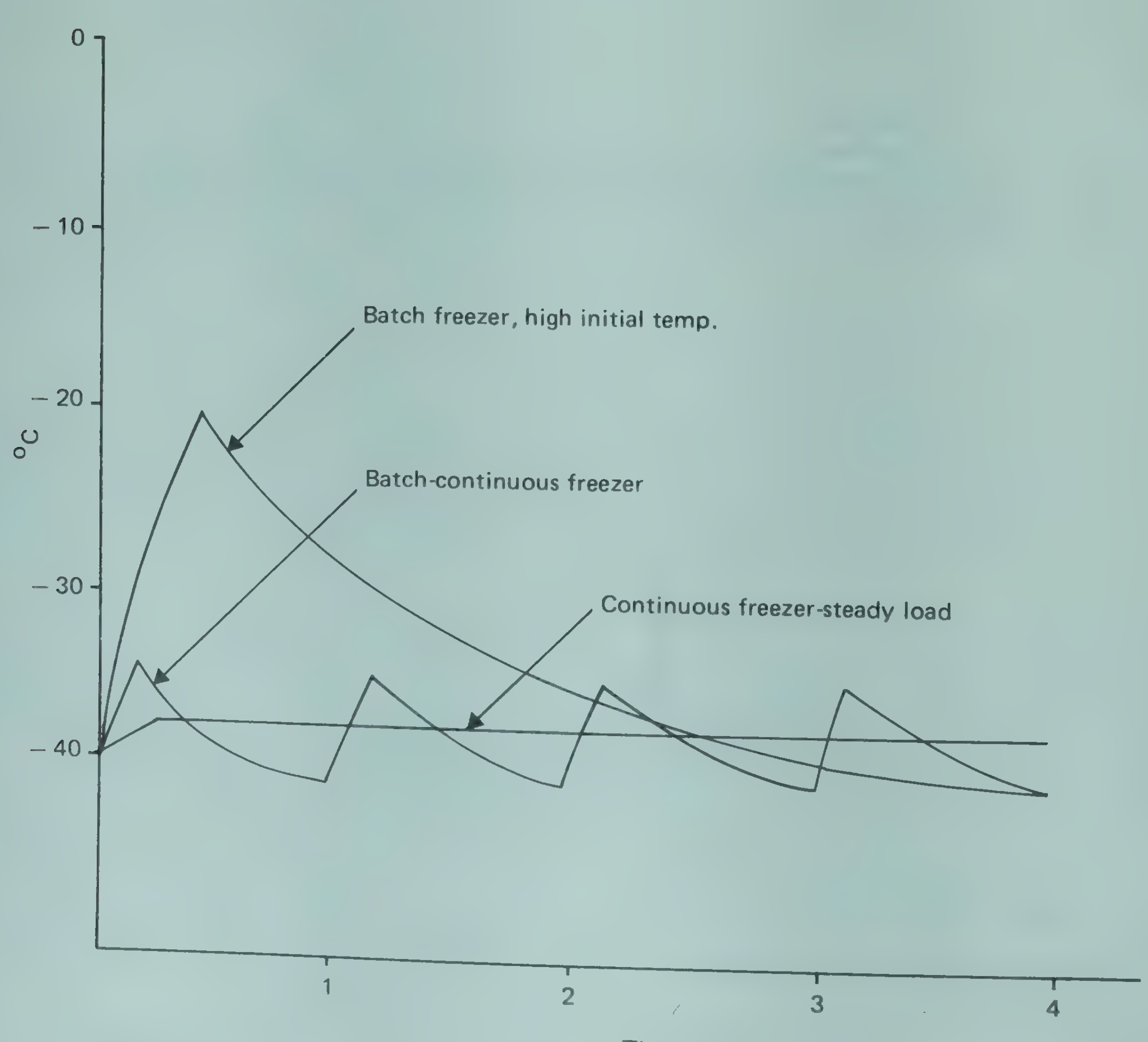
Other types of continuous air blast freezer. In fluidized ('bed') freezers, the product is fed into a trough and is 'fluidized' by a strong blast of cold air from below. This is suitable only for small products; it is particularly successful for garden peas. Its use in the fishing industry is very limited; small cooked and shelled shrimp is one of the few products that has been successfully frozen by this method.

A modified fluidized freezer, termed a 'semi-fluidized freezer', has been used for freezing certain fish. The product is loaded on to a conveyor and cold air is blown from below: portions are frozen individually.

Batch air blast freezer

Batch air blast freezers are available in a range of sizes; in the very small types the product may be loaded directly onto shelves; in larger freezers the product is loaded onto trolleys, or pallets which are then pushed or lifted into the freezer. The fish may be packed in trays or cartons; large fish may be loaded directly on to the trolleys. After freezing, the complete 'batch' is unloaded and the freezer can then be reloaded with a further batch. The refrigeration system must therefore be capable of coping with a very high initial load. In continuous or batch-continuous freezers the load is regular or steady (Figure 14).

Figure 14
Operating temperatures for different types of air blast freezer



Source: Redrawn from Food and Agriculture Organization of the United Nations, Rome (1977) FAO Fisheries Technical Paper (167).

The batch air blast freezer is extremely flexible; it can be operated as a true batch freezer or as a batch-continuous freezer. However, if the freezer has been designed to freeze a number of products with different freezing times (and different space requirements), it must not at any time be overloaded. For example, to freeze two products with freezing times of 2 hours and 1 hour in a freezer designed to freeze at a rate of, say, 1 tonne/hour, the freezer should be loaded as shown in Table 1. Thus, 2 tonnes of product A are loaded, frozen for 2 hours and removed. Then 1 tonne of product B can be loaded for freezing.

Table 1

Optimum loading of a batch air blast freezer

Product	Freezer capacity (t/h)	Load per 'batch' (t)	Freezing time (h)	Loading frequency	Freezing rate (t/h)
A	1	2	2	every 2 h	1
B	1	1	1	every h	1

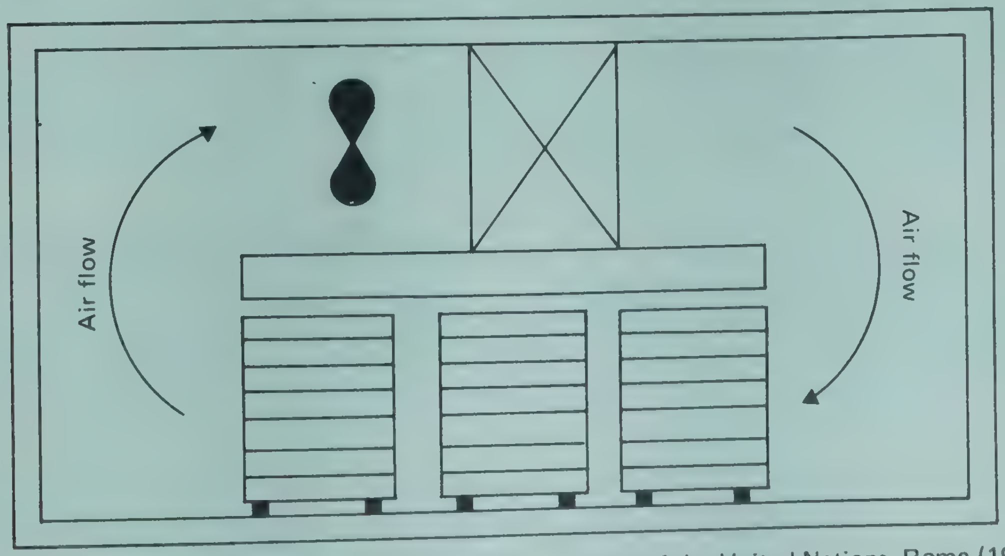
Batch air blast freezers can be used for 'mixed' batches. However if different products are frozen at the same time, close supervision is necessary to ensure that each product is frozen for the correct length of time and also that the freezer is not overloaded.

In many fish processing operations it is not practical to operate the freezer as a true batch freezer. Loading a fairly large number of trolleys can take a long time. Thus batch freezers, particularly the larger types, are often operated on a batch-continuous system. As each trolley is filled with fish it is loaded into the freezer. In addition to saving time this reduces the peak refrigeration load on the freezing machinery. Care must however be taken to avoid placing the warm trolley of fish between the evaporator and the partly frozen fish.

There is a wide variety of air blast freezer arrangements. Unfortunately some designs are poor. For efficient freezing, the air must flow evenly over the fish (Figure 15). All too often the air swirls about in the open spaces of the freezer room as shown in Figure 16.

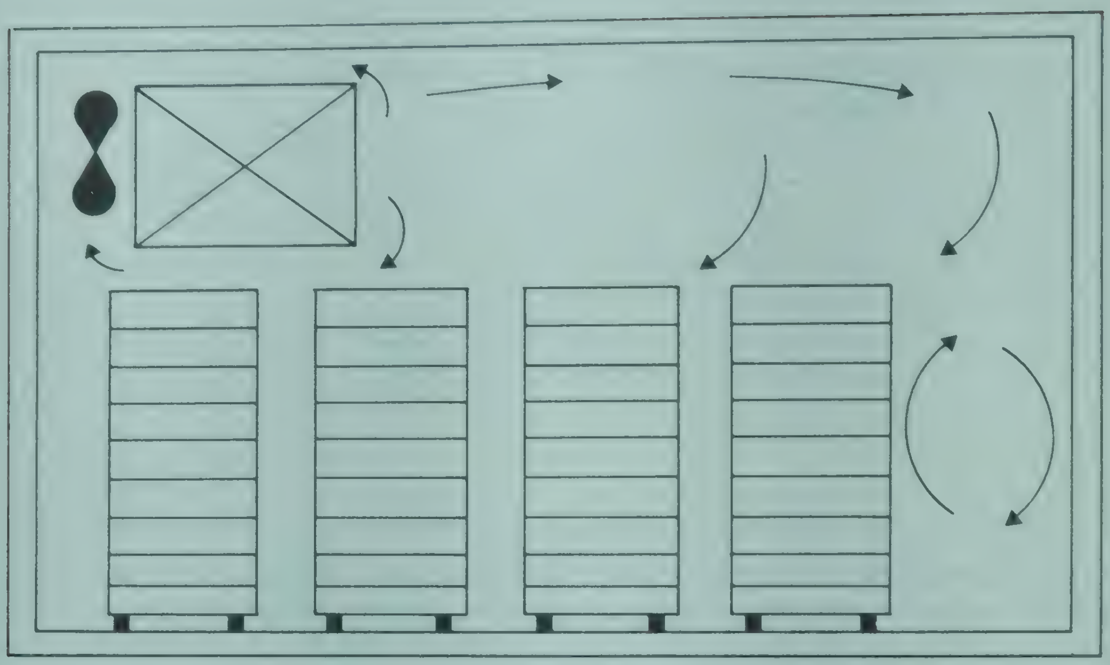
The method of loading trolleys and of stacking boxes on pallets is also important. Air must be able to pass over the product. When wooden spacers are used, they must follow the direction of air flow and not block it. Furthermore, the trolleys or pallets must be sited correctly in the freezer.

Figure 15
Batch air blast freezer with side loading and unloading



Source: Redrawn from Food and Agriculture Organization of the United Nations, Rome (1977) FAO Fisheries Technical Paper (167).

Figure 16
Room freezer with poor air flow over the surface of the product



Source: Redrawn from Food and Agriculture Organization of the United Nations, Rome (1977) FAO Fisheries Technical Paper (167).

PLATE FREEZERS

Air blast freezers and plate freezers are the most commonly used types of freezers in the fishing industry. Plate freezers, however, are not so versatile. The product, i.e. whole fish, fillets, shrimps etc., is frozen into blocks by contact with refrigerated plates.

The plates can be arranged vertically or horizontally with a refrigerant flowing through the plates. In modern freezers, the plates are made from extruded aluminium alloy; earlier models used vacuum plates with a refrigerant in an internal pipe grid. Hydraulic systems move the plates.

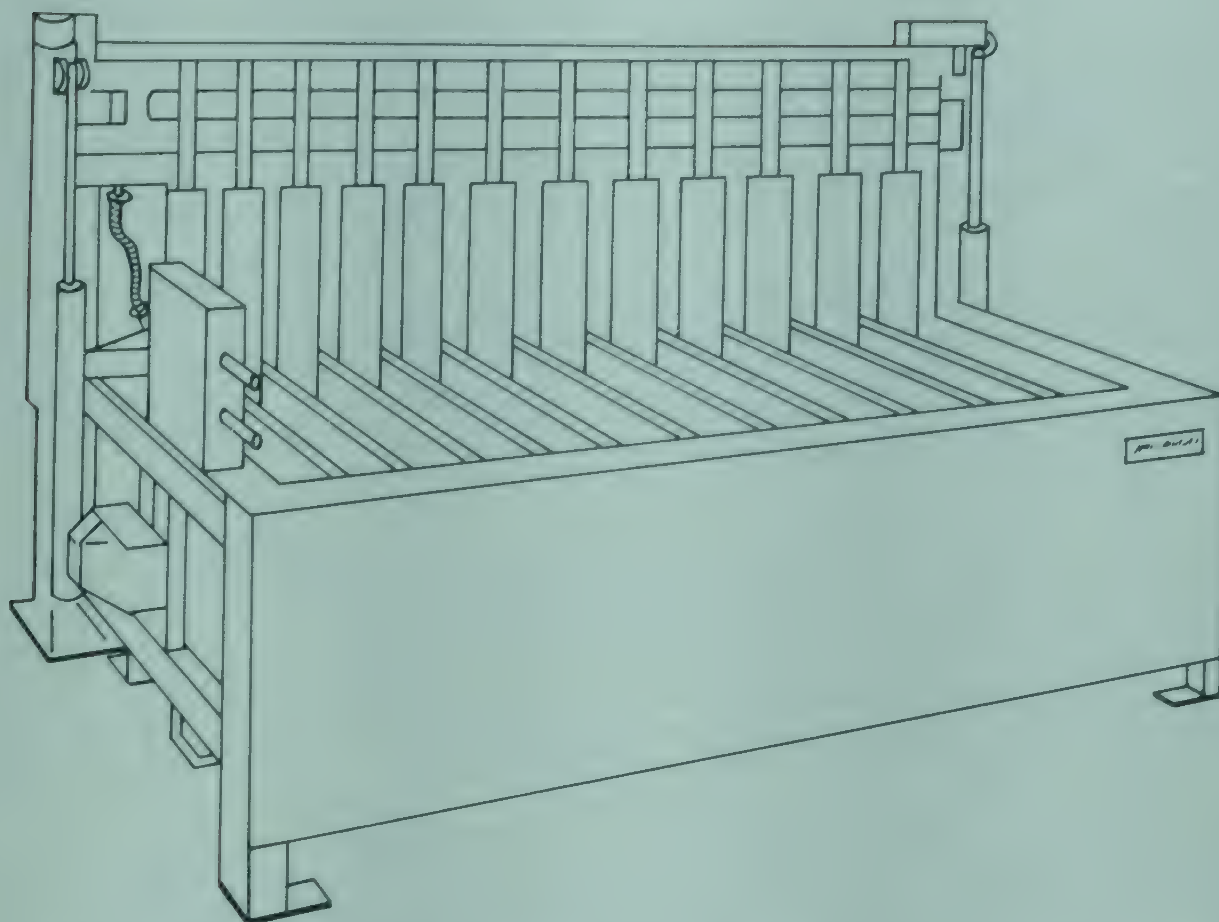
Vertical plate freezers (VPF)

This type of freezer is particularly suitable for freezing whole fish at sea and for bulk freezing. The fish are not packed in trays etc., they are loaded directly into the freezer (see Figure 17). Lean fish such as cod and haddock produce compact blocks but fatty fish such as herring do not make such rigid blocks; water is added to help to strengthen the blocks subsequent to handling and sometimes wrappers are used (in which case, longer freezing times are required). The maximum size of the blocks is about 1 x 0.5 m. Thickness can be from 25 to 130 mm. A hot gas or liquid defrost is required to release the blocks from the plates.

Different designs of VPF have top, side or bottom unloading; generally top unloading models are preferred. Ideally the freezer unit size should be matched to the rate at which fish are available for freezing but, if this is not possible, it is better to freeze a partial load than wait for a full load. VPF can be supplied with up to 30 stations.

If fish are loaded into the freezer with the plates at below 0°C, they will stick to the plates making it impossible to produce a dense block. As a result, freezing times will be longer because of the poor contact between the plates and the blocks. Such blocks will be less rigid and will take up more space in storage.

Figure 17
Multi-station vertical plate freezer with top unloading arrangement



Source: Redrawn from Food and Agriculture Organization of the United Nations, Rome (1977) FAO Fisheries Technical Paper (167).

Horizontal plate freezers (HPF)

In this type of freezer the fish are not in direct contact with the plates (see Figure 18). The product is always packaged in trays or cartons for freezing. Horizontal plate freezers are ideal for the production of pre-packed cartons of fish for retail sale and of homogeneous blocks of fillets (laminated blocks) for the preparation of fish portions. Blocks can be 32–100 mm thick and the freezer can generally adapt from the thicker to the thinner package.

If care is taken not to spill water on the plates during loading of the freezer, a defrost is not essential after each freezing operation: perhaps only once or twice a day suffices. Hot gas defrost is the quickest method of defrosting but a complete defrost may take 30 minutes or more. As with VPF, defrosted plates must be free of frost and ice and must be dried before re-use.

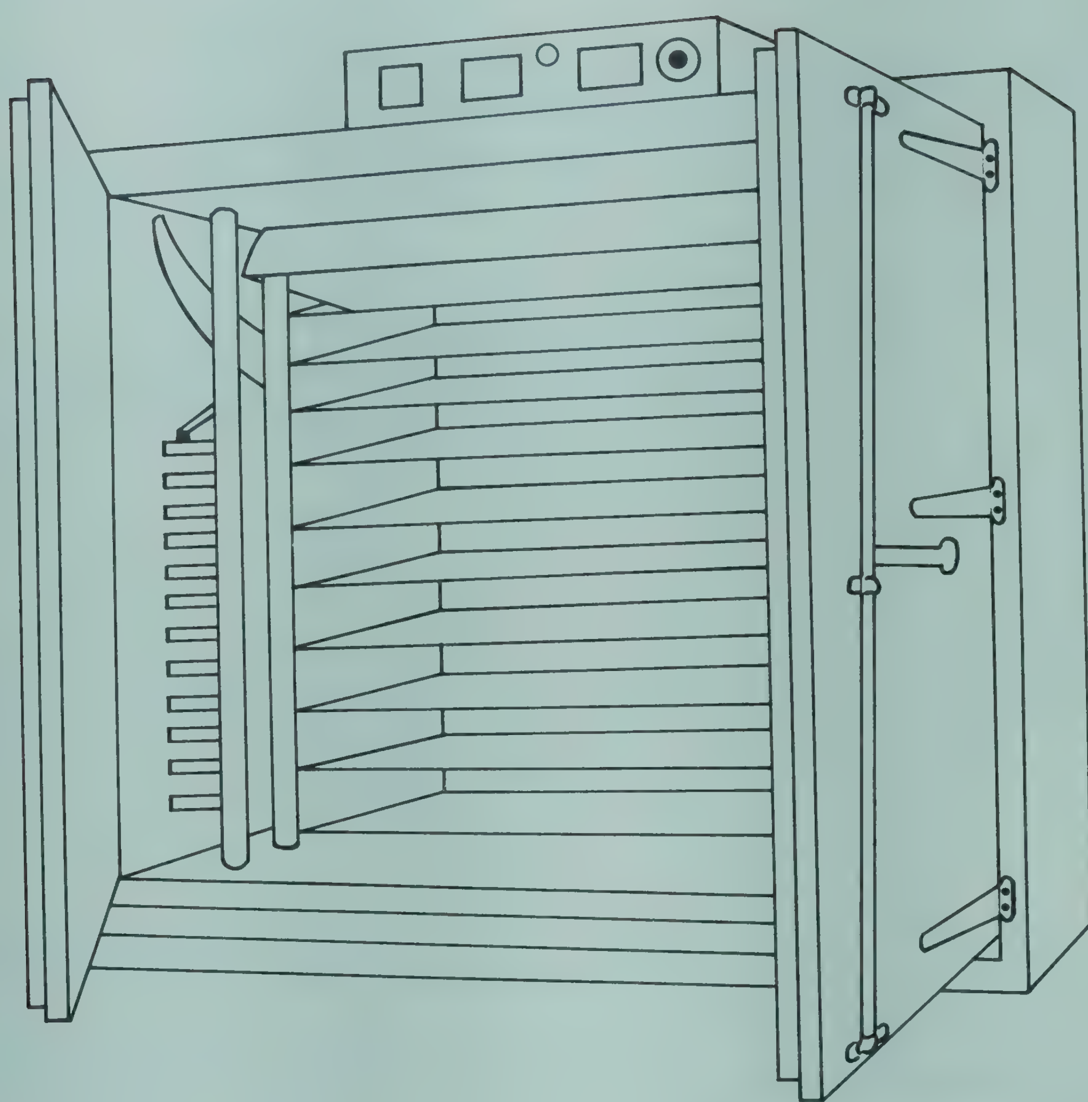
The plates of the HPF are closed by hydraulic pistons and the pressure can be varied to suit the product. For horizontal plate freezers to work efficiently, both the upper and lower plates must make good contact with the cartons or trays, which must be completely filled with the product.

SPRAY OR IMMERSION FREEZERS

In both of these methods of freezing the product comes into direct contact with the refrigerant. A number of immersion and spray freezers are used in the fishing industry but they tend to be of limited application, i.e. they may be suitable for only one type of specialised product or are expensive to operate. Examples are:

- liquid nitrogen freezers
- carbon dioxide freezers
- liquid freezant freezers
- immersion freezers.

Figure 18
Horizontal plate freezer



Source: Adapted from Food and Agriculture Organization of the United Nations, Rome (1977) FAO Fisheries Technical Paper (167).

Liquid nitrogen freezers

The refrigerant is sprayed directly on to the fish but, because liquid nitrogen is at such a low temperature and would cause physical damage, the fish are 'pre-conditioned' by a countercurrent flow of nitrogen gas. The temperature of the N_2 gas is about $-50°C$ when it first comes into contact with the fish and, as the fish progress through the freezer, it falls progressively to $-196°C$. Fish are placed on a stainless steel belt and, by the time they reach the liquid nitrogen spray, they are partially frozen. Before leaving the freezer, the fish temperature is allowed to reach equilibrium.

Liquid nitrogen freezing is very quick and the freezer is small (although storage space is also required for the liquid nitrogen tank) and easily maintained. The process as a whole is, however, very expensive (at least four times as costly as conventional air blast freezing) and another major disadvantage, as far as developing countries are concerned, is that liquid N_2 is not easily obtained.

Carbon dioxide freezers

Liquid CO_2 is injected into the freezer which operates similarly to the liquid N_2 freezer. In large units CO_2 is recovered; up to 80 per cent can be re-liquified and re-circulated. Freezers using this refrigerant must be well ventilated as high levels of CO_2 in the àir are dangerous.

As in other freezers which use a refrigerant for freezing the fish and hence depend on regular supplies, this type of freezer is not suitable for remote areas.

Liquid freezant freezers (LFF)

Liquid freezant freezers use a specially purified form of a liquid refrigerant called R12 (dichlorofluoromethane) which boils at −30°C at a normal atmospheric pressure. Fish are loaded on to one conveyor and are sprayed with the refrigerant and then drop into a tank containing R12. They are then transferred to a horizontal belt where more refrigerant is sprayed to complete freezing.

Although the refrigerant is recovered there can be considerable losses and, since recovery is by a conventional refrigeration system, liquid freezant freezers, unlike liquid N_2 and CO_2 freezers, have the usual requirements for operation and maintenance. The system is useful for IQF products but in some countries direct contact of foods with R12 is not approved.

Immersion freezers

Immersion in NaCl brine was one of the earliest methods used for freezing fish. Many other liquids have suitable refrigeration and heat transfer properties but cannot be used for freezing food products. Brine immersion freezing is still used for tuna which are to be canned. The fish are large and have a thick skin. Salt uptake is not excessive and, anyway, this is not detrimental in canned products which would otherwise have salt added.

Most effective brine freezing uses a eutectic solution of 22.4 per cent NaCl (85 per cent saturated) which can be maintained, as a liquid, at −21°C. Brine is circulated usually at about 0.2 m/s. The brine freezing tanks must be large (50:1, mass of brine :mass of fish) and the cooling coils must also be large. Other disadvantages of this system include the following:

- problems of corrosion
- product is difficult to handle
- product should be further frozen to −30°C, for storage.

OTHER TYPES OF FREEZERS

Other types of freezers are likely to employ combinations of two of the basic methods (e.g. the 'sharp' freezer contact and air blast) or a refinement of one of the methods (e.g. the drum freezer). These are not widely adopted.

The 'sharp' freezer usually consists of a room with cooling pipes arranged as shelves, spaced at about 25 cm, on which the product is frozen. Although the design is based on good principles, minor design details may be at fault and, in practice, the freezer does not perform well.

In drum freezers, the freezer is a rotating drum, cooled on the inside surface. It can be used for individual quick freezing of prawns and fillets (if they are placed parallel to the drum axis). The frozen product is scraped off the drum surface.

The continuous freezer with brine cooling is similar to continuous air blast freezing but the fish are frozen on a stainless steel conveyor belt, cooled by refrigerated brine which is pumped on to or sprayed across the lower surface of the belt. Freezing times are comparable to air blast freezers provided the products are thin. A conventional air blast system can be incorporated to cool the upper surfaces.

FREEZING TIME AND FREEZER OPERATING TEMPERATURE

Before we consider basic rules for freezing, two more terms must be mentioned.

Freezing time

To freeze fish quickly, the temperature at the centre of the fish must be reduced from 0 to –5°C in less than 2 hours. The size of the freezer and the capacity of the refrigeration plant depend on the quantity of fish to be frozen and the freezing time of the product. Since the recommended storage temperature for frozen fish is –30°C (in the UK) the freezer must operate at a lower temperature, e.g. –35 to –40°C. However, the surface of the fish will reach this temperature much faster than the centre of the fish. Thus, when the centre of the fish is at –20°C, the 'average' temperature of the fish on removal from the freezer will be close to –30°C.

Freezing time is defined as the time taken to lower the temperature of the product from its initial temperature to a given temperature (–20°C) at the centre. Freezing time is therefore the length of time the product must be in the freezer: the longer the freezing time, the larger the freezer must be for a given output, e.g., an output of 1 tonne/hour of a product that takes 1 hour to freeze will require the freezer to hold 1 tonne but, if the freezing time is 2 hours, the freezer must be large enough to hold 2 tonnes. Where several different products are to be frozen, the freezer should be designed to accommodate the product with the longest freezing time; the freezing rate for the freezer is then fixed.

Freezing time depends mainly on:

- freezer type
- freezer operating temperature
- air speed over the product in a blast freezer
- product temperature (initial and for storage)
- product thickness
- product shape
- product contact area and density
- species of fish
- method of loading: batch-continuous air blast freezing where the door/s are opened during the freezing cycle.

Freezing time can be calculated but there is usually insufficient information to make an accurate calculation. However, if a special type of thermometer, called a thermocouple, is inserted into the centre of the fish, the freezing time can be measured easily. Depending on the type and size of product and the method of freezing, freezing times can vary from a few minutes to many hours.

Freezer operating temperature

In some types of freezers, e.g. those in which the product is frozen by direct contact with the refrigerant, this temperature is fixed. For air blast and plate freezers the temperature can be varied to suit the customer's requirements. Freezer operating temperatures must be lower than the desired storage temperature but, for economic reasons, the freezer should not operate at too low a temperature.

Typical operating temperatures for various freezers are as follows:

Batch air blast	–35 to –37°C	air
Continuous air blast	–35 to –40°C	air
Plate	–40°C	
Liquid N_2	–196°C (N_2 gas at –50 to –196°C)	
Liquid freon freezant	–30°C (refrigerant) –40°C (condenser)	
NaCl brine	–21°C	
Drum	–45°C	

FREEZING DO'S AND DON'T'S

Freezing and cold storage cannot improve the quality of the fish. It is therefore essential that the raw material is as fresh as possible. We do not have time to out-

line all the rules for freezing different products in different freezers; the following are basic rules for freezing in an air blast freezer:

- Avoid delays before freezing particularly if freezing fillets
- Keep fish well iced, before freezing
- Follow hygiene practice outlined in earlier session
- Do not overload the freezer
- Do not underload the freezer; use 'dummies' if there is insufficient material
- If possible, freeze in open trays
- Trays should transfer heat readily, be robust and easily emptied and cleaned
- Dry and clean trays before re-use
- Load trays evenly on the shelves of the trolley
- If freezing in boxes, fill boxes with fish; keep air space to a minimum
- If freezing in boxes of fish on pallets, stack the boxes so that the air can pass over and under the fish i.e. use spacers
- Freeze for the correct length of time. This is particularly important if the fish or fillets are wrapped before freezing: the thicker the wrapping the longer the freezing time.

Treatment after freezing

As soon as the fish are removed from the freezer, they should be glazed or wrapped (if not wrapped before freezing).

Glazing. Forming a thin, even layer of ice around the product by spraying water, or by brushing or dipping in water, protects the product from dehydration and oxidation.

A dip-spray glazer has been found to be most suitable for obtaining a uniform glaze. The product travels on a belt and passes through the glaze zone where it is sprayed from above and at the same time passes briefly through a shallow trough of water.

Packaging. For retail consumer packs, wrapping should be provided. The following are a few points to note:

- As far as possible, the packaging should be air-tight
- It should 'fit' the product
- It should have some degree of impermeability to air and water vapour
- The type of pack used depends to a large extent on whether the product is wrapped before or after freezing
- Large single fish are difficult to wrap; they must be glazed
- Fish that are bulk frozen for further processing are glazed but usually are not wrapped
- Pallets with neatly stacked blocks of fish can be wrapped in a suitable plastic material.

Storage

Frozen products must be stored frozen in a cold store at the recommended storage temperature. The time between unloading the product from the freezer and transferring it to the cold store must be as short as possible. Handle frozen product with care; they are not as robust as they look.

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Instruments

Instruments of one sort or another are used by almost every industry and, in some, instrumentation can be extremely expensive. However, many of the instruments used in the fish industry are relatively cheap and their proper use can actually save costs. In many instances, adequate control of the process or product can be achieved only through the use of instruments.

Industrial instruments fall into two general categories: those which measure and those which control. In the fish industry, temperature, time, weight, air flow, pressure and moisture are perhaps the most commonly measured (or controlled) variables. A measuring instrument may indicate the present reading or situation e.g. a 'spot' reading thermometer, or it may show what has happened over a period of time e.g. a recording thermometer. A controlling instrument is a measuring instrument with a built-in switch or regulator to keep the conditions within certain specified variables such as a thermostat which controls the temperature of a smoking kiln. Some of the more elaborate and expensive instruments may measure, record and control.

In this session we will look at the basic principles of some of the instruments which can be used in the fish processing industry.

THERMOMETERS

During fish handling, processing, transportation etc., temperature is perhaps the most important factor to measure and control. At high ambient temperatures fish spoil very rapidly and, therefore, they must be cooled quickly. The correct freezing temperature must be employed for rapid freezing and the temperature of smoking must also be controlled.

During any process the temperature must be checked frequently and, if it has fallen or risen, corrective action must be taken. Also, the device itself must be checked regularly for correct functioning.

There are various ways in which the temperature may be measured; different types of thermometers are more suitable for particular sets of circumstances.

Liquid expansion

A familiar example of this type of thermometer is the common clinical mercury-in-glass thermometer. As the temperature rises, the mercury in the bulb expands along the fine capillary tube which is marked in degrees Centigrade (or Fahrenheit). The main disadvantages of liquid-in-glass thermometers are that they are fragile; are often difficult to read; they must be read 'in situ'; the column of mercury can break. They are however relatively cheap. Mercury freezes at −39°C and boils at 357°C. Mercury-in-glass thermometers are made to cover a variety of temperature ranges within this range. For lower temperatures, a different liquid must be used, such as alcohol which has a useful range from −79 to 71°C; a pink dye is usually added to the alcohol.

Another type of liquid expansion thermometer is the mercury-in-steel thermometer. The capillary can be made very long and can be bent around corners; hence it is more suitable for measuring temperatures at a distance from the bulb. The temperature is measured indirectly usually by a Bourdon (pressure) gauge, which can be linked to a pointer moving on a dial or fixed to a pen which traces a record on a moving chart.

The response of liquid expansion thermometers is sluggish and for this reason they are most suitable for measuring 'steady' temperatures, for instance in a cold room. Also, because the bulb is large, and breakable if glass, it cannot be used for inserting into fish etc. Other types of thermometers are used for measuring rapid changes in temperature and for insertion into fish.

Solid expansion

Metals expand when their temperature is raised but the extent to which they expand varies from one metal to another. Some steels containing nickel and chromium hardly expand at all when their temperature is raised over a wide range; other metals such as copper expand considerably. This phenomenon is used in bimetallic strip thermometers and in thermostats. The bimetallic strip consists of two strips of dissimilar metal joined along their length. As the temperature rises, one side of the strip expands more than the other and causes the bimetallic strip to curve; the degree of curvature depends upon the temperature rise.

Electrical resistance

This type of thermometer depends upon changes in electrical resistance in a wire with change in temperature. It measures resistance to the flow of electricity passing along a very fine coil of wire in the sensitive tip.

The advantage of the resistance thermometer is that the tip can be extremely small and the response is very rapid. The sensitive element (thermistor) can be fitted into a variety of different types of probes, i.e., general purpose, heavy duty, surface, hypodermic needles and catheters. The electric circuit, meter and battery, necessary for measuring changes in the resistance, can be fitted into a small portable box which may be at some distance from the sensitive tip.

Thermocouples

If two wires of different metals are joined in a loop and one junction is heated, a small electric current will flow round the loop; opposite voltages are produced at each junction and this difference between them causes the current to flow. The voltage depends on the metals and the temperature difference between the hot and cold junction. Providing that the voltage produced corresponds regularly to the temperature difference, this system can be used for measuring temperature.

The voltages produced are small and, hence, the measuring device must be extremely sensitive. This can be a voltmeter in the circuit which measures the thermocouple voltage or another voltage, from a battery, may be fed into the circuit to oppose the thermocouple voltage. Measurement of the voltage that is required to stop the current flowing gives a more accurate measure of the thermocouple voltage but sometimes the direct method, using a voltmeter, is preferred. The apparatus for measuring the electrical output may be complicated and expensive.

In many of these types of theremometers the readings are recorded on a chart; others may be adapted to switch heaters on or off as in thermostats. Thus thermocouples are used mainly to measure temperature but also, in some cases, to control temperatures.

The advantages of thermocouples are that the response is rapid; the junction can be even smaller than the thermistor; the thermocouples themselves are generally cheap.

BALANCES AND SCALES

Balances or scales are used frequently in the fishing industry. For example, fish are sold by weight; weight losses are monitored during freezing and storage; fish are weighed before and after drying to establish the percentage moisture. Although many different types of balances are available, they are based either on the spring or beam principle.

Spring balances

The object to be weighed is attached by a hook, bucket or pan to one end of the spring; the other end is fixed to the main body of the balance. As the spring extends, a pointer moves and the weight is indicated on a scale. Spring balances are simple and robust and give a rapid reading. However, they are not always very accurate and, in time, the spring may distort.

Beam balances

The simplest type of beam balance is, in effect, a see-saw with a pan at each end. The object is placed on one pan and known weights are added to the other until the beam is horizontal. The 'beam' principle is used in many different types of balances for example, the steelyard, platform scales and a number of direct-reading pan balances which are used in shops, markets, factories etc.

Beam balances used in the fish industry are generally very accurate, reliable and robust. Often the balance will have a 'tare' facility.

TIMERS

Timing is important in a number of fish processing operations, particularly for freezing and brining. A variety of simple, robust timers is available. These may be clockwork or electric, some have a bell incorporated which can be set to sound after the required period of time, others may switch on a warning light, while others can switch off the equipment at the end of the process.

An approximate idea of time can also be important, e.g. time before fish are iced, time to load and unload freezers, delays during processing etc.

PRESSURE GAUGES

Pressure gauges are used for direct measurement of pressure, although this is usually the pressure difference between, say, the steam in the boiler and the air outside, and for indirect measurement of temperature and the flow of liquids or gases.

The simplest and cheapest type is a U-tube which is filled with a suitable liquid i.e., one which does not evaporate quickly, such as mercury or a light oil. Pressure-measuring instruments with a pointer which moves on a dial are preferred. Many of these operate on the Bourdon tube principle. The Bourdon tube is essentially an oval-shaped or flattened tube which may be C-shaped or a flat spiral. As the pressure increases inside the tube it tends to become less flattened and tends to straighten; the degree of 'straightening' depends directly on the pressure. One end of the tube is fixed and the other is attached, via gears and levers, to a pointer on the dial. Care must be taken when using the Bourdon gauge not to exceed the stated pressure as the walls of the tube are extremely thin and the gears and levers are easily damaged.

Bourdon tubes are widely used. Their use in conjunction with the mercury-in-steel thermometer has already been mentioned. They can register pressures below and/or above atmospheric. A specially designed gauge with a spike, which when stuck into a can makes an air-tight seal, is used for measuring pressures inside the can.

HYDROMETERS

Hydrometers measure density of liquids. Density is the weight of a known volume of a substance and is often related to the density of water: 1 cubic centimeter of water weighs 1 gram; 1 cubic centimeter of benzene weighs 0.8724 grams. This relative density is called specific gravity; the specific gravity of benzene is 0.8724.

Although hydrometers measure density, usually what is of more interest is the information they give about what is in the liquid. A special type of hydrometer called a brineometer or salinometer is used to find out how much salt is in a brine solution. Brineometers are marked in degrees; these may be salinometer degrees (a saturated solution is 100°, pure water is 0°), Baumé degrees or Twaddell degrees (as shown in table below). Thus a saturated brine solution (at 16°C) contains about 360 g/l and an 80° brine, which is commonly used in fish smoking, contains 270 g/l. For practical purposes, the errors in using salinometers at higher temperatures are comparatively small and can be neglected.

Brine strengths as measured on various hydrometer scales at 60°F (16°C)

Salinometer Degrees	Specific Gravity	Baumé Degrees	Twaddell Degrees	Per Cent Salt By Wt.	Salt (g) per Litre of Water
0	1.000	0.0	0.0	0.000	0.0
10	1.019	2.7	3.8	2.640	27.0
20	1.038	5.3	7.6	5.279	55.6
30	1.058	7.9	11.6	7.919	85.8
40	1.078	10.5	15.6	10.558	117.7
50	1.098	12.9	19.6	13.198	151.7
55	1.108	14.1	21.6	14.517	169.5
60	1.118	15.3	23.6	15.837	187.9
65	1.128	16.5	25.6	17.157	206.6
70	1.139	17.7	27.8	18.477	226.2
75	1.149	18.8	29.8	19.796	246.3
80	1.160	20.0	32.0	21.116	267.1
85	1.171	21.2	34.2	22.436	288.7
90	1.182	22.3	36.4	23.755	310.8
95	1.193	23.5	38.6	25.075	333.9
100	1.204	24.6	40.8	26.395	357.9

HYGROMETERS AND MOISTURE METERS

The measurement of moisture content or humidity of the air is important for many drying and smoking operations; an instrument called a hygrometer is used for this purpose. The moisture of the final product can be determined by weighing (as mentioned earlier) or by using a moisture meter.

Hygrometers

Horsehair. The simplest and crudest type of hygrometer is the so-called horsehair hygrometer. Certain substances such as horsehair, catgut and paper absorb water depending on the relative humidity. As they take up water, they expand and can be made to operate a pointer on a scale. These devices are, however, almost impossible to calibrate and are very unreliable.

Wet and dry. Wet and dry hygrometers consist of two thermometers, the bulb of one is kept moist and is usually in a muslin bag, the other is kept dry. As air blows over both thermometers, water evaporates from the wet bulb and cools it. The difference in temperature between the two, known as the wet bulb depression, depends on the relative humidity. After reading the dry bulb temperature and the wet bulb depression, the relative humidity is obtained from a table which gives humidities for a range of dry bulb temperatures and wet bulb depressions.

The wet and dry bulb hygrometer is the most reliable method of measuring relative humidity. However, the following points should be noted:

- keep the wet bulb moist with clean water
- if there is no reservoir, after moistening, leave for half a minute before reading
- read both bulbs within a few seconds
- the wet bulb must be downwind
- air speed must be more than 1 m/sec.

Other types of hygrometers, based on different principles, are available but none is very robust and will not be considered here.

Moisture meters

The standard method of determining moisture content has been mentioned earlier. A known weight of sample is dried overnight in an oven at about 105°C and re-weighed; the percentage moisture is then calculated. This method is very accurate and reliable but is slow. There is a commercial instrument, which uses an infra-red lamp, for detecting moisture. This is suitable for dry materials such as fish meal and the moisture content can be found in about 20 minutes. For wetter fish flesh, there is a method whereby a known weight is heated in a liquid which does not mix with water (e.g. toluene) and the water is collected and measured. This method takes about an hour and, since toluene is highly inflammable, it should be used only by trained technicians.

Various types of meters have been developed for rapid estimation of water content. One of these depends on electrical conductivity changing with moisture content. Although it is suitable for seeds and grains, it has not proved to be very successful with other products because salt affects the instrument. In another method, a known weight of the sample is mixed with calcium carbide; acetylene gas and heat are produced and, if carried out in a sealed container, the pressure generated can be measured on a Bourdon gauge which is graduated for moisture content.

FLOW METERS

Measurement of the flow of gases is carried out in the fishing industry mainly in relation to air circulation in blast freezers (and blast thawers) and smoking kilns. Various instruments are available which give a direct or indirect reading. Direction of air flow can be found simply by holding a 'streamer' at arm's length in the air current.

Anemometers

Anemometers are delicate instruments which measure air flow by the speed of rotation of a small fan. It is placed in the desired position, the counting mechanism is switched on and turned off after an accurately timed period, say one minute. This operation is then repeated several times. A problem with meters of this sort is that, however carefully they are made, some energy is lost in driving the fan. They cannot be used for slow air speeds of less than 17 m/min. Also, the mechanism is extremely delicate and is damaged by high temperatures and smoke. Direct reading anemometers tend to be rather expensive.

Velometers

Another means of measuring air flow is to measure the force exerted on a pivoted vane, placed in the air stream. A velometer is an instrument in which the vane moves in a specially shaped channel and the force is opposed by a small spiral spring; a pointer attached to the vane moves across the scale. Velometers can be placed directly in the air stream or can be connected by specially-designed inlet and outlet tubes to the air or smoke.

Pitot tubes

The pitot tube measures gas flow by the determination of pressure difference. The air speed affects the height of the liquid in the tube according to a known mathematical relationship. One type of pitot tube has a detecting head, which must face into the air stream, and at the other end there is a two-way junction which is connected via tubes to an inclined manometer. The manometer measures the pressure difference between what is called the impact pressure and the static pressure; it is very useful as it can detect small pressures.

Anemometers, velometers and pitot tubes are used for 'spot' tests and, generally for any measurements at any time, a number of readings are made and an average is obtained. In some instances, constant monitoring is required. A number of devices are available, most of which depend on measuring the difference in pressure in front of and behind an obstruction in a flow of gas or liquid. The orifice meter is the most common of these.

Orifice meter

After the gas or liquid is forced through the orifice, it does not immediately spread out but forms a 'neck'. The pressure here is lower than in the main stream and the difference in pressure is measured with any suitable pressure-measuring instrument and the velocity is calculated. Orifice meters are simple, cheap and robust but, as they do obstruct flow, the pump or fan which is producing the air flow has to generate additional pressure to operate the meter.

SMOKE METERS

The optical density (OD) of smoke is measured by determining how much light, from a lamp of known brightness, will penetrate a given, fixed distance. Although this system can detect only droplets in the smoke and not the vapours, it gives a useful measure of the smoke thickness. Light is focussed through a lens system on to a photo-electric cell and the current produced is measured on a suitable meter which gives OD/unit distance. Both the lens and the photo-electric cell must be protected against the tar deposits from the smoke; electrically-heated glass windows are placed in front of each. The cell and the light source must be in the kiln but the meter can be some distance away.

Other types of smoke meter can 'meter' the smoke in much the same way as an electricity meter shows how much electricity has been used. Another type, in which the smoke density is recorded on a graph, is much more expensive and, although it has a number of advantages, has the disadvantage that the detecting and measuring devices are fixed together.

Chilled and frozen fish storage

We have talked at some length about chilling and freezing fish and we have seen that these are two distinctly different processes. We are now going to talk briefly about cold and chill stores. It is convenient to talk about the storage of frozen and chilled fish in one session.

STORAGE OF CHILLED FISH

Using ice

It is quite feasible to use ice for keeping fish, once chilled, at chill temperatures for long periods. Ice melts at a set temperature (0°C) and by adding ice to fish at various intervals it is possible to make up the ice that has melted away. This will compensate for melting caused by the surrounding air, i.e. by heat leakage. To minimise the amount of heat leakage from the surrounding air insulation is often used.

Chill stores

Chill stores are designed to maintain pre-chilled fish at chill temperatures. They must *not* be used to:

1. chill fish that has not already been chilled using ice or other cooling media;
2. freeze fish.

The temperature in a chill store must be above the freezing point of the fish so that any ice that is present on the fish when they are placed in store can continue to melt and keep the fish cool. There will also be no danger of fish becoming partially frozen.

Methods of storage

Chilled fish are most commonly stored in boxes. The different types of box used for storage of iced fish were mentioned earlier. Whole and gutted fish are usually stored in boxes up to 45 cm deep although delicate fatty fish such as herring and sardines should not be held in boxes more than 20 cm deep or physical damage will occur to fish at the bottom. Prepared fish products such as fillets etc. are held in shallow boxes usually not more than 15 cm deep. Boxes of fish entering the store should contain some ice which will continue to melt during storage and prevent drying of the surface of the fish. Boxes are stacked in blocks with air spaces between each block so that air can circulate around the boxes. It is important that boxes are not stacked against the walls of the store or directly on to the floor.

In many small chill stores stowage is done by hand and so it is important that the height of stacks of fish in boxes is not more than can easily be managed by hand.

STORAGE OF FROZEN FISH

Cold stores

Cold stores are designed to maintain pre-frozen fish at freezing temperatures.

They must *not* be used to:

1. freeze fish that has not already been frozen;
2. produce chilled fish.

All products entering the store must be at or near the frozen storage temperature which for fish is recommended to be – 30°C. Fish that has been quick frozen to – 30°C will keep in edible condition for many months if stored correctly. The exact period of storage depends on a number of factors:

1. The particular species of fish.
2. The fat content of the fish.
3. The treatment the fish has received prior to freezing.
4. The physiological state of the fish.

Very fresh cod (a temperate-water non-fatty fish) stored for less than 24 hours on ice before freezing will keep for 8 months in prime condition and up to 4 years before it becomes inedible if glazed and packaged efficiently and stored at – 30°C.

Herring (a fatty temperate-water fish) will keep for 6 months in prime condition and up to a year in good condition under the same regime.

Method of stowage

Pallets. Frozen fish is often stored in cardboard cartons or boxes which are made up into pallet loads for ease of handling with fork lift trucks. The advantages of using pallets are that the product can be divided into unit loads and is easily handled using platform trolleys or fork lift trucks.

Irregularly shaped and large fish which are not packed into boxes must be packed in pallets with wire mesh walls; these are often used for whole tuna. Each pallet should be constructed to withstand the weight of up to four loaded pallets on top. Stacks of pallets should be placed clear of the walls and roof and raised above the ground to ensure air circulation around the product. Recommended distances are as follows:

From floor	100 mm
walls	200 mm
ceiling	500 mm

There should also be space between stacks to allow circulation of air and also to ensure that removal of a pallet from one stack does not disturb its neighbour.

Bulk stowage is used for storage of whole fish such as tuna. It is not, however, to be recommended.

Hand stowage. Stowage of fish into small stores is often by hand on to shelves along the walls of the store or into stacks. Where labour is cheap or only small quantities are being handled, this is usually more economical than mechanical handling.

WHAT IS INSULATION?

If we have two bodies which are at different temperatures touching one another the warmer body will tend to transfer heat to the cooler one: the warm body will drop in temperature and the cooler one rise until the temperatures are equal. An insulant is a material that, if placed between the two bodies at different temperatures, will

slow down the rate of heat exchange. Air is an extremely poor conductor of heat and will slow down the rate of exchange of heat between two bodies at different temperatures. However, because air is a gas it will transfer heat between the two bodies by convention, i.e. warm air will move from the hotter body to the cooler one and vice versa. If we can prevent the air moving between the hot surface and the cold surface then the insulation effect will be much greater. This is the principle on which insulants used for cold stores, insulated boxes etc. are based. Small pockets of air are trapped in a medium so that the air cannot move around. In principle the smaller the size of the air pocket the better the insulant properties of the material. It should be remembered, however, that the medium itself will conduct heat from one body to the other so that the smaller the air pocket the greater may be the conduction across the material. The efficiency of an insulation material in preventing heat flow is measured as thermal conductivity (k) which equals the amount of heat in kilocalories passing every hour through one square metre of material one metre thick when there is a 1°C temperature difference between the two surfaces of the material. The more efficient the insulation of the material the lower the value of k. The table below gives k values for a number of materials.

Material	*k value*
Wood	0.14–0.16
Brick	0.7–0.86
Cork	0.04
Glass fibre	0.03
Polyurethane foam	0.02–0.03
Expanded polystyrene	0.02–0.03
Air	0.02

It can be seen that materials such as cork, polyurethane foam and expanded polystyrene have very low k values and for this reason are often used for insulation.

To get an idea of the value that insulation plays in keeping fish cool we will make some simple calculations using as an example a box of fish in ice. We wish to calculate the amount of heat leakage into a simple wooden box of iced fish through its lid and compare it with the heat leakage into a box with an insulated lid.

Calculation

To calculate the amount of heat entering through the lid of a simple wooden box, held at 30°C and containing ice, (area 0.4 x 0.6 m, the wood being 0.01 m thick). The heat flow through the lid depends on four factors.

1. The area of the lid. 0.4 m x 0.6 m = 0.24 m^2
2. The thickness of the lid = 0.01 m
3. The temperature difference between the outside and the inside of the box = 30°C.
4. The k value of the material of the lid = 0.15.

$$\text{Heat flow} = \frac{\text{k x area x temperature difference}}{\text{thickness}}$$

$$= \frac{0.15 \times 0.24 \times 30}{0.01} = 108 \text{ kcal/hour.}$$

Calculation 2

All dimensions and temperatures as for calculation 1 but using 0.01 m of polyurethane foam instead of 0.01 m of wood.

k value for polyurethane foam taken as 0.02

$$\text{Heat flow} = \frac{0.02 \times 0.24 \times 30}{0.01}$$

$$= 14.4 \text{ kcal/hour.}$$

In practice much thicker insulation is used which would reduce the heat gain still further. Insulation is not only used in simple ice boxes but also in the construction of cold and chill stores.

The simple calculations made above can be scaled up so as to calculate the amount of heat entering a cold store or chillroom and so aid in deciding on the refrigeration equipment necessary for the store. This would normally be done by the store designers during planning.

Types of insulation

Ideally an insulant should have the following characteristics:

Low thermal conductivity

Be water-resistant and non-absorbant. It should also be a good vapour seal and should not rot if it becomes wet.

Lightness in weight

Structural strength

Stability i.e. it should not compact down or move after insulation

Low cost

Non-toxicity

Resistance to compression

Non-flammability

Be vermin proof.

We shall now look at a few common insulants.

Cork: Expanded cork was one of the earlier insulants used and it is still used to some extent today. It has good thermal conductivity characteristics but if badly produced is not resistant to water vapour. It is resistant to compression and is difficult to burn. Because of the scarcity of suitable trees its price is relatively high and this is one of the main reasons why it is not used commonly today.

Glass fibre: Glass fibre matting has a thermal conductivity lower than cork but is permeable to moisture. It also has no structural strength or compression resistance and tends to settle after installation if not properly installed. It is however fire-resistant.

Expanded and extruded polystyrene: These two materials are used widely, these days, for insulation. The materials have low thermal conductivity and can be produced in self-supporting panels. Unfortunately they have low compression resistance and, although they do not burn, they are destroyed at a fairly low temperature (75°C), and become fragile when subjected to ultra violet light.

Polyurethane foam: The low initial thermal conductivity of polyurethane foam gradually increases with time. Its main advantage is that it can be foamed *in situ* on to the surface that requires insulation. It can also be produced in self-supporting panels. The vapour-resistance is good but it will burn at 200°C and emits toxic substances during combustion.

Granular materials: Sawdust, crumb polystyrene, granular cork, rock insulants (vermiculite) etc. are often cheap and readily available where other types of more rigid insulation are not. These materials are often better than no insulation at all but tend to settle after installation and so become less effective. They are also not resistant to the passage of water vapour.

FREEZER BURN – WHAT IS IT?

Frozen fish, if unprotected by glazing or a wrapping material which is impervious to moisture, may lose moisture from its surface. This drying is due to the temperature difference between the fish and the cooling coils of the refrigeration plant. The amount of water required to saturate air depends on the temperature of that air; the colder the air the less the moisture it can hold. As cold, water-saturated air leaves the cooling coils it gradually warms up and is able to take up more moisture. When the air comes into contact with fish in the store it takes up moisture from the fish and becomes re-saturated. This warm, moisture-laden air reaches the cooling coils and becomes super-saturated so that the moisture is released as frost on to the coils. Frozen fish that has suffered severe drying during storage has a white, toughened, dry and wrinkled appearance, which is known as 'freezer burn'. This condition not only produces a reduction in weight but also affects the texture and appearance of the fish.

FAT OXIDATION

The fat of fish may become rancid during storage. Fish oils combine readily with oxygen and some enzymes in the fish accelerate this reaction. Salt can also accelerate it. Glazing the fish prior to frozen storage will help to alleviate both fat oxidation and freezer burn as long as the glaze remains intact. During very long low-temperature storage the glazing layer will be reduced and may need to be renewed.

FROST HEAVE – WHAT IS IT?

Large low-temperature stores built directly on to the ground often need ventilation and insulation under the floor or an under-floor heating mat in order to prevent the ground below the floor freezing. If the ground does freeze and ice builds up below the store it can lead to damage of the floor and structural damage of the cold store. This phenomenon is known as 'frost heave'. A similar condition can occur if the insulation is not sufficiently well protected from the ingress of water by a vapour seal and moisture enters the insulant layer and freezes. This not only reduces the effectiveness of insulation but can also cause structural damage to the walls of the store.

STORE DESIGN

The complexities of actual design of chill and cold stores will not concern us but some points are worth mentioning.

1. Since chill store temperatures should allow ice to melt the floor surface must be non-slip, even when covered in water, and should also be drained.

2. The walls must be adequately insulated and vapour sealed to prevent passage of heat and water vapour.

3. When deciding on the size of store, allowance must be made for movement of people, trolleys, boxes etc. within the store.

4. Where many door openings are envisaged, with much movement of fish and people etc. in and out of the store, it may be advisable to have an inner and outer door with an airlock between. As an alternative or even as an addition to double doors, an air curtain to prevent excessive loss of refrigerated air at the door entrance may be advisable.

5. It is advisable that the store be inside the building so as to minimise warming of the structure by direct solar radiation. This is particularly important in tropical climates.

6. If wheeled trolleys, fork lift trucks, etc. are to be used in the store the floor must be sufficiently strong and durable.

7. The amount of refrigeration required depends on a number of factors which must be taken into account at the design stages.

(1) ambient temperatures and the efficiency of the proposed insulation which will govern the quantity of heat leaking into the store

(2) quantities and temperature of products entering the store

(3) the number of door openings

(4) the size of the store.

When asking for quotations from manufacturers of chill and cold stores, the following information should be given in addition to the information listed above:

1. Ambient air temperatures.
2. Water supply: quantities, pressure and quality (i.e. fresh, brackish, sea water).
3. Availability of land. A plan of the proposed site is always useful.
4. The capacity of the store.
5. The stowage method to be used.
6. The electricity supply available. Most plants require a 3-phase supply of electricity. The voltage and cycles of the supply should be given.
7. A separate generator may be required; if so, specify other equipment to be run from the generator.
8. The type of refrigerant required, e.g. ammonia, freon 12, 22 or 502 etc. depending on local availability and cost.
9. The spare parts requirements.
10. Local expertise, if any, in installation of refrigeration machinery.

MANAGEMENT DO'S AND DON'T'S

1. Never put fish into the store that is not pre-chilled or frozen to the temperature of the store.

2. Produce should be rotated within the store on a first-in, first-out principle.

3. All boxes, pallets, cartons etc. of fish entering the store should be labelled with date, species, type of product, weight etc.

4. For maximum efficiency from the refrigeration, cold air must be able to flow around the product. Boxes etc. should not be stacked directly either on to the floor or against the walls.

5. If the store has more than one entrance, two or more doors should not be opened at any one time. Do not open the doors more often than is essential.

6. All products in frozen store should be protected from freezer burn and rancidity by wrapping, glazing etc.

7. Store temperatures should be monitored and checked regularly.

Quality: control and assessment

In this session we will look at what is meant by quality, how it is controlled and the methods of assessing quality. The importance of quality is recognised increasingly as more and more countries become involved in exporting highly-priced fish and fish products such as snappers, shrimps, prawns, caviar etc., and a host of products such as canned fish, dried fish, fish meal etc. The exporting country must meet the quality standards of the importing country. However, many tropical countries which have an active export industry may, as a nation, suffer from protein deficiency and there is, therefore, a need to improve the quality of fish for home consumption. These improvements should be aimed at a level whereby wastage, through deterioration and poor handling and preservation, is reduced so that more fish can be made available for the home market.

QUALITY—WHAT IS IT?

In simple terms, the quality of a food can be defined as those characteristics or attributes which make it acceptable to the consumer. Generally, the consumer will pay more for fish that he or she considers to be of higher 'quality' and will continue to buy it as long as the quality remains constant. Consumer preferences, however, vary from country to country, from region to region and even between individuals; and these preferences may well change over the years. In order to control quality it is, therefore, essential to know what the consumer is looking for when buying fish.

Some of the characteristics of quality are inherent in the fish immediately it is caught (intrinsic quality); others are associated with the post-harvest fate, i.e. quality deterioration, or spoilage, and loss of quality which may occur during handling and processing (extrinsic quality). From the consumer's point of view, some of the more important factors that determine quality are:

> species; appearance of fish and flesh; ease of preparation; odour; flavour; freshness; size; presence or absence of bones; absence of parasites; freedom from food poisoning bacteria; condition; composition; packaging.

The consumer will know from experience which types of fish he prefers and what he considers to be 'good quality'. There are other factors of which he may not be aware; these may be controlled by legislation, e.g., certain chemical additives or colouring materials may be prohibited or, in some countries, the total number of bacteria permitted may be restricted.

QUALITY CONTROL—WHAT IS IT?

Quality control can be defined as the maintenance of quality at a level that satisfies the consumer and that is economical to the producer. Quality control is normally

based on agreed procedures and specifications which are designed to maintain quality or reduce defects:

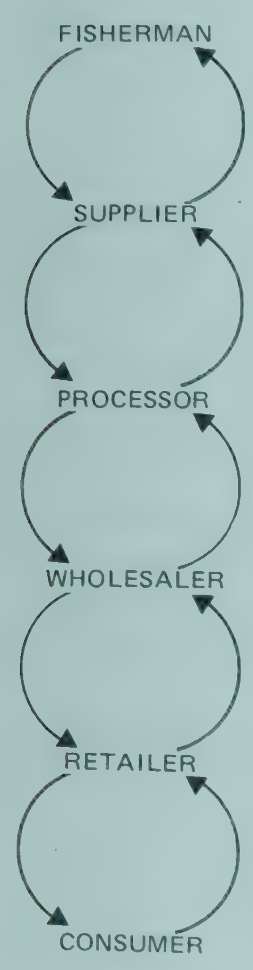
- of the raw material
- during all stages of processing
- of the final product.

Inspection is a vital function of quality control; it is normally a commercial activity but official inspection is required in some countries by law (mandatory inspection). Inspection is the examination of the fish or fish products by visual, physical, analytical or microbiological means to ensure it meets the required standards of specifications.

Purpose

The purpose of quality control is to keep the customer happy and to maintain or increase profitability to everyone involved in selling and/or processing fish. If quality falls, the customer will complain and may not return to the shop or may not buy the product again. It is, therefore, very important for quality to be maintained, particularly for 'branded' products. Also, loss of profitability can occur when fish products do not comply with local, national and international standards (see the circular feedback situation in Figure 19).

Figure 19
Typical marketing chain



When and where is quality control (QC) applied?

Quality control is applied either actively or passively at all stages in the chain from capture to retail. These are briefly as follows:

On the boat — The catch is sorted; unmarketable fish are discarded. Fish may be sorted according to species and size.

At the wholesale market	Fish are selected again by size, species and quality.
During processing	Selection for size and quality. Fish of lower quality may be channelled into another process or discarded. Random sampling at different stages. QC also applied to water supply, equipment, personnel etc.
Final product	Random sampling.
During storage	Random sampling. NB frozen, dried, salted, canned fish etc.
By the retailer	Selection for species, size etc.
By the consumer	Selection for species, size etc.

Cost of quality control

Active quality control, i.e. taking samples for testing, is a costly and time-consuming operation. The cost of mandatory inspection is inescapable and is borne to some extent by all parties. It can be argued that, if no benefits accrue from QC, it should not be carried out; however the benefits are difficult and sometimes impossible to measure. Quality control is generally accepted as being essential for any firm or industry that wants to maintain a good reputation. The processor will pass the cost of QC on to the customer but must not price the product out of reach of the consumer. The cost of QC should not be more than 1 per cent of the retail value.

Passive QC, i.e. visual selection on the boats, at markets, shops etc., tends to be an integral part of the catching or buying operation.

METHODS OF ASSESSING AND SELECTION FOR QUALITY

The quality of the raw material and/or the final product can be assessed by sensory, mechanical and physical, biochemical and chemical, and microbiological methods. Over the years, many methods have been developed in an attempt to find the most reliable and most suitable index for use in QC testing. The disadvantages of most methods are that they are time-consuming and require specialised facilities; the results are not produced immediately and the sample is destroyed in the test.

For all fisheries, whether developed or developing, a means of assessing the quality of the raw materials is essential. There is no point in using 'poor quality' fish for expensive processing. In many tropical fisheries, however, elaborate QC procedures cannot be undertaken; a simple, rapid method of assessing quality is required.

Sensory methods

Sensory methods depend entirely on the human senses. All except hearing are used in the fishing industry. The importance of sensory assessment cannot be overemphasised; frequently there is no choice but to use sensory methods. Furthermore, the final criterion for quality is whether the fish is acceptable to eat.

The sense of sight is used at almost all stages to assess size; species; colour (of whole fish and of flesh); colour and condition of the gills and eyes; presence of slime; physical damage; condition of the belly (in developed fisheries, however, many species are gutted immediately after capture); presence of bones in fillets; attractiveness of the packaging etc.

In any visual assessment of the whole fish the sense of touch is also used; a firm fish is preferred to a soft fish. The sense of touch is also used when eating the fish, i.e. in assessing the texture of the flesh.

Taste and smell are powerful senses in assessing quality. When examining the raw fish, the odour of the gills and the general odour of the fish are important indicators of freshness. In the cooked fish odour, flavour or taste and texture are assessed. If off-flavours and off-odours are present, the fish will be rejected.

The tongue can detect four basic tastes: bitter, sweet, salt and acid. Fresh fish have a sweet taste but as they spoil, bitter flavours develop. For some products it is necessary to detect levels of saltiness and acidity but, generally, for these properties chemical methods of detection are preferred. Other factors which are important in 'tasting' fish are rancidity and the presence of bones in fillets etc.

Sensory methods of assessment are, strictly speaking, subjective; they are based on the likes and dislikes of the individual. The consumer may say he or she prefers one type of fish to another but no score or number can be given to a purely subjective assessment. However, two forms of sensory assessment have been developed in an attempt to give an objective judgement; visual inspection and taste panel. If people are trained, they can make a dispassionate and unbiased descriptive assessment of the product and a score or grade can be assigned.

Visual inspection. In many countries grading systems based on visual inspection are in use commercially. A visual and olfactory assessment of the whole fish will almost certainly be the first means of assessment in any developing fishery. It is recommended that iced storage trials be carried out for all commercial species to establish their maximum shelf life in ice. At intervals during storage, detailed descriptions of the visual changes should be made, samples should be taken and cooked for tasting and, if possible, samples should also be tested for microbiological counts. From a knowledge of the visual/organoleptic changes it is possible to predict the numbers of days a fish has been in ice. The acceptable length of storage is confirmed from taste panel findings. For fisheries which are considering a distribution of fresh fish, this type of information is essential.

Taste panel. A trained taste panel may consist of as few as six members; their scores will be averaged to give a more useful assessment. Simple preference testing, e.g. do you like or dislike the product?, and 'no-preference' testing, e.g. are two samples the same or different?, can also be used in some circumstances. No training is necessary.

Mechanical/physical

Mechanical/physical methods can be employed for:

- grading fish according to size
- measurement of fat and moisture content
- testing firmness of flesh in frozen, chilled and canned fish
- measuring the degree of spoilage in chilled fish.

I will deal briefly with the first three. A number of machines for size-grading are available and are in common use in many countries; sorting according to species cannot be done mechanically. In developing fisheries, grading would almost certainly be by hand. Instruments can be used for rapid determination of fat and moisture but chemical methods are more accurate. Also, there are a number of instruments which have been developed for testing the firmness of fresh, chilled and canned flesh but few are in commercial use.

As chilled, whole fish spoil changes occur in the electrical properties of the skin and flesh. Based on this principle, two types of direct-reading instrument have been designed. The readings must however be 'calibrated' for each species. Such instruments would be of particular value at port markets and factory reception areas; the 'inspector', buyer or factory manager could rapidly check the freshness of batches of fish. It is hoped that the recently designed British meter (GR Torrymeter) will prove to be a reliable, robust and accurate 'tool' for checking and monitoring quality. The main advantages of this type of instrument are that it:

- is small enough to be carried
- does not damage the fish
- gives an instantaneous result
- is independent of human senses or judgement
- does not require highly trained or skilled personnel.

Reading must, however, be made on a number of fish in order to obtain an average. In the GR Torrymeter an averaging facility is incorporated; a reading is obtained only after the meter has been placed on 16 fish.

The control of time and temperature is essential in all fish handling and processing operations. Therefore, it can be claimed justifiably that the clock and the thermometer are the two most important physical instruments. Their sensible and careful use can go far to obviate the need for other more advanced instruments or expensive methods of inspection and checking.

Chemical and biochemical

For a number of fish and fish products it is important to know their composition. Chemical determinations for protein, fat, moisture, salt and ash (including sand etc.) are generally called 'proximate' analysis. It is considered essential that every developing fishery should establish the proximate composition of all commercial species and how it varies throughout the year. Details of the methods can be readily obtained from text books, scientific papers etc.

Chemical and biochemical methods, used for the assessment of quality/spoilage of chilled, frozen and otherwise processed fish, rely mainly upon the estimation of compounds produced by bacterial and autolytic enzymes and the oxidation of fats e.g.:

	Tests include
Bacterial action	Trimethylamine (TMA) only for marine species
	Total volatile bases (TVB)
	Total reducing substances (TRS)
Autolytic action	pH and lactic acid levels
	Sugars and sugar phosphates
	Enzymatic assays of nucleotide breakdown products
Fat oxidation	Thiobarbituric acid (TBA)
	Peroxide value
	Iodine value
	Free fatty acid

Estimations of compounds produced by bacterial action are usually considered to be 'spoilage indicators'; nucleotide breakdown products, e.g. hypoxanthine, may be considered 'freshness indicators' which can, to some extent, predict the shelf life of a given consignment of fish.

Nearly all these methods require specialised equipment and laboratory facilities. For this reason TVB, which can be carried out with simple and readily available glassware and chemicals, is often the only method suitable for use in the tropics.

Microbiological

Micro-organisms in fish and fish products are divided into two broad categories: spoilage organisms, which are almost always present in large numbers, and organisms of public health significance (pathogens) which, although not usually present in large numbers, are hazardous and are the main concern of micro-biological quality control.

Routine microbiological testing measures total numbers of bacteria present, or the presence/absence of specific pathogens. For both methods the sample is homogenised in a suitable liquid, diluted and 'plated out'; the plates are then incubated. Numbers of bacteria are counted. For total plate counts, a nutrient medium (agar) is used; for pathogens, special media that favour the growth of the particular group of organisms are used. Microbiological methods are fairly laborious and often only the larger companies, public heath laboratories etc. have the necessary facilities.

INTERPRETATION OF RESULTS AND ALIGNMENT WITH STANDARDS

There is no point in carrying out any methods of quality and sensory assessment unless the results are related to standards. This may be a local, national or international standard or an unwritten specification. Who sets the standards up? The chain may be as follows;

consumer:	retailer
retailer:	wholesaler
wholesaler:	processor
processor:	supplier
supplier:	fisherman.

Often it will be short-circuited, i.e. the customer buys directly from the fisherman. In most cases it is the processor who has to ensure that the product meets the standards, particularly in the case of international and national standards which are set up by Government bodies and international organisations.

How and why are the standards set up?

The ultimate destiny of fish is to be eaten by the customer and it must, therefore, be safe to eat and of an acceptable quality. It is impossible and impracticable for fish to be tested by tasting at each point of sale. Furthermore, as mentioned earlier, tasting is subjective. Standards, for which a given figure or range of figures can be specified, are set up. Microbiological, biochemical, physical etc. methods of testing are a substitute for eating (testing for pathogens is a separate issue). Where discrepancies arise in a product, a definite result is more valuable than a subjective appraisal. All fish cannot be sampled. Random samples are therefore taken and there is always the risk that these do not represent the whole batch. Statistical principles can be applied to establish how many fish should be tested.

Products must meet standards whether they are written or unwritten. For example, if chilled fish is to be distributed for sale two days later, its 'quality' before distribution must be such that it will be still of acceptable quality to the consumer; if it is not, it should be redirected. Where 'quality' problems occur in the export of frozen fish and shrimps, the source of the problem must be found.

HOW TO MAINTAIN QUALITY

It must be remembered that no form of processing will improve the quality of a spoiled or partially spoiled fish. Therefore it is important to maintain quality (as far as is possible) by good handling practices at all stages from capture to consumption. The session on chilling and hygiene have covered most of what is referred to as 'good housekeeping'. The major factors to be controlled in order to reduce spoilage and maintain quality are:

- time
- temperature
- contamination
- damage.

Time. Because fish is so perishable, particularly at high ambient temperatures, it is important to keep all delays to a minimum. A knowledge of the length of time that fish can be left at ambient temperatures before icing; the length of time they can be stored in ice and stored frozen is essential.

Temperature. The raw material should be chilled as soon as possible and kept chilled before processing and during all stages of preparation of the fish. The temperature of freezing, cold storage, drying, smoking etc. must be controlled. These may be specified.

Contamination. Fish are readily contaminated during handling and processing. Control is effected by good hygiene and sanitation, i.e. good housekeeping. Problems of contamination of fish caught in polluted waters can be difficult to overcome. The problem should be treated at the source.

Damage. Measures to control damage are straightforward. Avoid treading on the fish, piercing with hooks, bending while in rigor, etc. Glazing and suitable packaging will protect frozen products. Other products may be packaged to protect them against physical damage and/or the effects of humidity, insect infestation etc.

OTHER AREAS FOR QUALITY CONTROL

We have concentrated on quality aspects of the raw material and will now deal briefly with specific problems that may occur.

Canned fish

Under high ambient temperatures and in areas of high humidity, there is a tendency for cans to 'blow' and corrode and, generally, keeping times are shorter than in cooler, less humid climates. Attention should therefore be paid to the method of storage and length of storage.

Two major problems can occur in canning frozen tuna. 'Honeycombing', a condition in which the flesh is perforated by holes, is thought to occur if the fish were partially spoiled before canning. Quality control should therefore be applied before canning. 'Greening' appears only after the cans have been cooked. The green discoloration is associated with a modification of the haem pigment. There is a method for predicting greening and, in practice, processors take samples of the raw flesh for testing.

Parasites

A parasite is an organism which can only live on or inside another living animal or plant. Fortunately, although many parasites are unsightly and if found by the consumer can be a quality problem, few are harmful. Parasitic infections in humans which result from eating improperly cooked, infested fish are, however, a problem in some areas, e.g., a tape worm which occurs in Europe, South America and Asia.

Naturally toxic fish

Although the vast majority of food fishes are intrinsically safe to eat, ingestion of certain fish and marine invertebrates causes a variety of illnesses and even death. There are three types of fish poisoning:

- puffer fish poisoning
- ciguatera fish poisoning
- paralytic shellfish poisoning.

Puffer fish poisoning is a public health problem mainly in Japan. These fish are always toxic; the toxin (tetrodotoxin) is concentrated in the gonads but is sometimes also found in the liver and intestines. It can be fatal. If the gonads are skilfully removed and the flesh is thoroughly cleaned, puffer fish can be eaten safely. In Japan, legislative controls range from prohibition of sale to licensing people who prepare the fish in special 'fugu' restaurants.

Ciguatera fish poisoning can be caused by eating the flesh of a wide variety of fish and shellfish from tropical and subtropical waters. Fish which have been incriminated are not always toxic and the reasons why they become toxic are somewhat obscure but are thought to be connected with changes in the nature of their food. The toxin is not destroyed by cooking. Ingestion of toxic fish is rarely fatal but symptoms can be unpleasant and can last for several months. Quality control measures can be difficult to apply although, in areas where species are prone to toxicity, it is said that the local fishermen can identify suspicious fish which are then rejected.

Paralytic shellfish poisoning which may result from eating mussels, clams, etc. is particularly well-known and documented. Outbreaks occur sporadically and unpredictably and have been reported in North and Central America, Europe, Asia and Australia.

The molluscs become toxic only when certain types of dinoflagellates (unicellular organisms) are present in large numbers in the sea; they assimilate the toxins without being harmed themselves. It is possible to assay toxins and control measures are introduced when a toxin reaches 80 mg/100 g. The area is closed to commercial harvesters and warnings are displayed on the beaches.

Puffer fish and potentially toxic fish (ciguateric species) are found mainly in tropical waters. Because of the trend towards utilising 'trash' fish, there is a danger that toxic fish may be inadvertently included. Anyone responsible for handling such fish should be aware of this problem.

CODES OF PRACTICE AND STANDARDS

In the 1960's the need for a broad international approach to the establishment of quality standards was recognised and, in 1962, the Codex Alimentarius Committee was set up; standards are being prepared for all fishery products. Some form of certification of quality and the conditions under which they were produced may become a necessity for fishery products to survive on world markets.

Codes of Practice have also been drawn up. These are of value in relation to compliance with Codex Standards and are a source of useful advice for countries wishing to improve existing handling and processing practices. Codes of Practice for Fish and Fishery Products, dealing with technical matters, are prepared by the Department of Fisheries in FAO. These Codes of Practice are aimed mainly at the developed countries and it is hoped that a Code, which concentrates on the areas where handling, processing etc. of tropical fish differs from that of temperate fish, will be prepared.

A number of countries have set up national standards or specifications for a variety of fish and fishery products. Every effort should be given to encourage their development in tropical countries.

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Drying, smoking and salting

BASIC PRINCIPLES

We have talked at some length about the use of reduced temperatures to preserve fish in edible condition. In many situations refrigeration facilities and ice are not available and traditional fish preservation methods are based on the curing process. There are three basic factors used, either singly or in combination, in the production of cured fish.

Removal of Water

Water is essential for life and bacteria and enzymes in fish flesh require plenty of water to function efficiently. The removal of moisture can slow down or even stop completely the action of spoilage bacteria and enzymes. Bacterial action stops at moisture contents of 25 per cent or below.

Smoking

Some of the chemicals in wood smoke will destroy spoilage bacteria and this effect can be used to advantage in preserving fish. The production of smoke implies a fire and the generation of heat. When fish is smoked it becomes dried and also in certain instances is cooked. Cooking will destroy the action of enzymes and will kill many bacteria because of the high temperatures involved. Smoked products with a long storage life owe their keeping qualities to drying and cooking, rarely to the chemical preservation of wood smoke alone.

Addition of salt

Common salt (sodium chloride), if present in fish in sufficient quantities, will slow down or prevent most bacterial action. In addition, salt aids in the removal of water from fish by osmosis. When fish is placed in a solution of salt stronger than the concentration of salts in the fish cells, water passes from the cells into the brine until the two solutions are of equal strength. In addition to the removal of water, salt will penetrate the flesh and so help to preserve it.

When salt is added to fish before drying, less water needs to be removed to achieve preservation and a product with a water content of 35–45 per cent, depending on the amount of salt present, is often dry enough to inhibit the action of bacteria.

SALTING

The main way in which salt is used in traditional fish processing is in conjunction with drying. Used as a preliminary to drying it replaces some of the water present

in the flesh. The factors which affect the rate of uptake of salt and, therefore, the amount of water replaced are:

- the higher the fat content, the slower the salt uptake
- the thicker the fish, the slower the diffusion of salt to the centre
- the fresher the fish, the more slowly salt will be taken up
- the higher the temperature, the quicker the salt uptake

During subsequent drying the presence of salt has the following effects:

- the higher the salt concentration, the greater the replacement of water and therefore the less water that remains to be removed during drying.
- the higher the salt concentration, the less water that needs to be removed to produce a satisfactorily preserved product.
- the higher the salt concentration, the more slowly the fish dries.
- salt tends to absorb moisture from the air and, at relative humidities of more than about 75 per cent during the drying process or during the subsequent storage, fish will not dry further or may even take up moisture.

If salt is used the product will give a better yield and probably be of better quality (i.e. have longer shelf-life) than non salted fish. Salt also acts as a deterrent to insect pests which can invade fish during drying and subsequent storage. Although from these points it would seem advisable always to use salt as a preliminary to drying there are various factors which must be considered. These include:

The economics of production: i.e. whether salt is available in sufficient quantities and at sufficiently low cost for a fish processor to be able to recover the expense involved through better yields and through higher prices charged for the product.

Consumer resistance: in many countries there is a marked preference amongst the fish-eating population for non-salted fish. It has proved extremely difficult to change the eating habits of people to accept salted fish and for this reason many programmes aimed at improving dried fish quality in less developed countries have failed.

Often the salt that is readily available in sufficient quantities and at the right price is of very poor quality and so not suitable for use on fish.

Salt quality

Chemical composition Common salt is in its pure form sodium chloride (NaCl), however many commercial salts are produced by the evaporation of sea water (solar salt) and contain chemical impurities. The main impurities are usually salts of calcium and magnesium. Calcium and magnesium chlorides absorb moisture and, at high relative humidities, can cause the salt to become wet. In general however, calcium and magnesium salts if present in small quantities can be advantageous. Only when they are present in excess can they be troublesome because they can also cause brittleness. Magnesium sulphate causes brittleness and calcium brings about excessive whitening of the fish.

Physical impurities Many salts, particularly solar salts, contain physical impurities such as sand and mud. The quantity of detritus present depends largely on the means of production but can be as high as 35 per cent by weight. As far as possible the use of salts containing physical impurities should be avoided.

Microbiological quality We have said that the spoilage bacteria of fish are inhibited by the presence of salt, however, there are certain bacteria that are able to grow and multiply in high concentrations of salt. These bacteria which are red or pink can be present in large numbers (up to 100 000/g) particularly in solar salt and, if present in salt used for curing fish, can cause a phenomenon known as pinking.

In addition moulds are often present, particularly in rock salt, which can cause a condition known as 'dun' in dried/salted fish.

Ideally, salt used for fish curing should be free from microbial contamination but it is rarely possible to obtain a pure salt at the right price and in sufficient quantities.

Grain size Salt is available in a variety of grain sizes depending on the amount of grinding that it has undergone. When producing a brine it is useful to have a fine-grain salt so that it dissolves quickly and easily. However, for dry salting, a larger grain salt is more appropriate because small grains act too quickly on the fish surface and remove moisture so fast that the surface becomes hard and prevents penetration of salt to the inside of the fish. This is known as 'salt burn.'

Salting methods

Salt can be used as a preliminary to drying in two basic ways; as dry salt or dissolved in water as brine.

Dry salting In its simplest form dry salting consists of rubbing grains of salt into the surface of the fish. It is important that all parts of the fish are covered and salt is applied more liberally to the thicker parts of the flesh to obtain an even penetration.

Another way of using dry salt is to produce alternate layers of fish and salt. It is important that salt covers all the fish and is applied both above and below. In kenching, the fish and salt are stacked so that the water, drawn from the fish by osmoisis, can flow away. In pickling, the fish and salt are held in a water-tight tub and a brine or pickle is formed. Generally salt penetration is more even and thorough with pickling than with kenching. It is also possible to use kenching and pickling to produce preserved salt fish that is not subsequently dried.

Brining Dissolving salt in water produces a brine. In fish processing a brine strength of between 80 and 100 per cent saturated is usually recommended. (This is equivalent to about 270—360 g of salt to each litre of water.) Brine must be made up to within these limits if it is to be effective and the salt must be completely dissolved before use. In many instances the salt available for fish processing is impure and more rather than less, salt should be added. Potable water should always be used.

After being prepared by, for example, splitting, gutting and scoring, the fish are immersed in brine for various periods depending on the size, fat contant, consumer demand etc. The period of immersion is usually determined by trial and error for a particular fish species. In Zambia a rough and ready guide is 1 hour for 1 pound weight for non-fatty fish and, for fatty fish, 1¼ hours per pound. These immersion times give about 8—10 per cent salt in the final sun-dried and smoked product that is popular in Zambia. For products requiring different salt concentrations the brining time can be altered accordingly. It is often advisable to rinse the excess brine from the surface of the fish after brining so that unsightly white crystals of salt do not appear during subsequent drying.

DRYING

The term 'drying' usually implies the removal of water by evaporation, but water can be removed by other methods, for example, by applying pressure, using absorbant pads, and adding salt.

During evaporative drying water is removed in two distinct phases. Firstly water on or close to the surface of the fish evaporates; the drying rate depends on the surface area of the fish, the air temperature, the speed of air movement over the fish and the relative humidity of the air. If air conditions remain the same the drying rate will remain constant. This phase is known as the 'constant rate period'.

Once the surface water has evaporated, water can only evaporate as fast as it can reach the surface of the fish from within. The rate of movement of water from the

deeper parts of the fish becomes slower as drying proceeds; this second stage is known as the 'falling rate period'. During the falling rate period the drying rate depends on:

- the nature of the fish; fat in fish flesh retards water movement
- the thickness of the flesh
- temperature of the fish
- the water content

Provided that the air moving over the surface of the fish is not saturated with moisture, the drying rate is independent of the state of the air. If drying during the constant rate period has been very rapid, a condition known as case hardening occurs. The surface layers dry quickly, producing a hard layer which is impervious to the passage of water. This layer then prevents the migration of water during the falling rate period and the centre of the fish can become spoiled although, to all intents and purposes, it looks well dried.

Sun and wind drying

Many traditional fisheries use the energy of the sun and/or wind to dry fish. Exposing fish to the warming effects of the sun will help to remove moisture and natural wind and air currents will carry away the moisture from the surface of the fish. It is important when using natural energy sources that they are utilised to the full. Many traditional fishermen dry fish on the ground, on rocks along the sea shore and on sandy beaches.

Some fish processors use mats and reeds etc., laid on the ground to prevent contamination of the fish by sand, dirt, mud etc. Drying fish on the ground and at ground level has many disadvantages and the use of raised drying racks should be encouraged wherever possible because:

- at ground level air movements are usually slow; at a metre or so above the ground, air currents are stronger.
- laying fish on the ground does not allow drying from the underside of fish. If the fish are dried on racks with an open-work top, air will pass under the fish as well as over them. The fish therefore dry more quickly.
- racks keep fish cleaner by not allowing them to come into contact with dirt on the ground.
- racks keep fish out of reach of domestic animals, such as dogs and chickens, and pests, such as rats, mice and crawling insects. These often contaminate and steal fish that are dried at ground level.
- sloping racks allow any excess moisture to drain away, thus eliminating pockets of water that can form in the gut and gill cavities causing slow drying in these areas.
- fish dried on racks are more easily protected from the rain; the racks can be simply covered with a sheet of polythene or other waterproof material. If fish are on the ground, covering will protect them from falling rain but not from ground water.

Drying times are reduced by using raised racks and the product will almost certainly be of better quality than fish dried on the ground.

Raised drying racks can be constructed at little cost using bamboo, branches of trees, reeds etc. Raised racks should be sited in areas with low humidity and with good prevailing winds.

Fish may take up moisture if the relative humidity rises above about 75 per cent. In tropical countries, there is often a diurnal rise and fall of temperature and humidity. For this reason it is often recommended that fish be taken indoors overnight. This will not only prevent the fish from being 'rewetted' at high humidity but will also protect them from rain, theft and predators. If the fish are stacked or press-piled overnight the internal water will migrate more quickly to the surface, thus accelerating subsequent drying.

Blowflies lay eggs on fish during the early stages of sun drying, as they will on fresh fish, but become progressively less attracted to the fish as it dries. If the fish can be dried sufficiently quickly, i.e. before the eggs hatch into larvae, they are not normally a problem. Brining or salting before drying will deter blowfly attack. It is possible to reduce attacks by spraying below drying racks etc. with a contact insecticide. It is important that the insecticide does not contaminate the fish.

In Iceland and Norway a product known as stockfish has been produced for many centuries. Cod which has been headed is hung in the open air to dry. At the low ambient temperatures in these countries the fish is preserved and gradually dries over a period of about 6 weeks to a moisture content of about 15 per cent. This product has a shelf life of several years if stored correctly and is mainly exported to African countries and to the Mediterranean area.

Mechanical driers

To allow drying regardless of weather conditions and to produce a more uniform product various mechanical driers have been developed. The purchase of a mechanical drier and the cost of fuel for its operation are higher than building a set of drying racks for natural drying; however, the labour costs can be lower.

Mechanical driers are used experimentally and commercially in a number of fisheries. These are often made on a one-off basis to suit local conditions and using locally available material. A few commercial firms produce driers for purchase as prefabricated units.

Most driers have a horizontal flow of air across the product, placed on open-work trays on a trolley. The trolley is either pushed through the drying tunnel or into the drying chamber. The air passing over the fish can be heated with steam, electricity, gas or oil.

SMOKING

The use of smoke to preserve fish is an ancient practice. Various smoking methods are practised in many different countries.

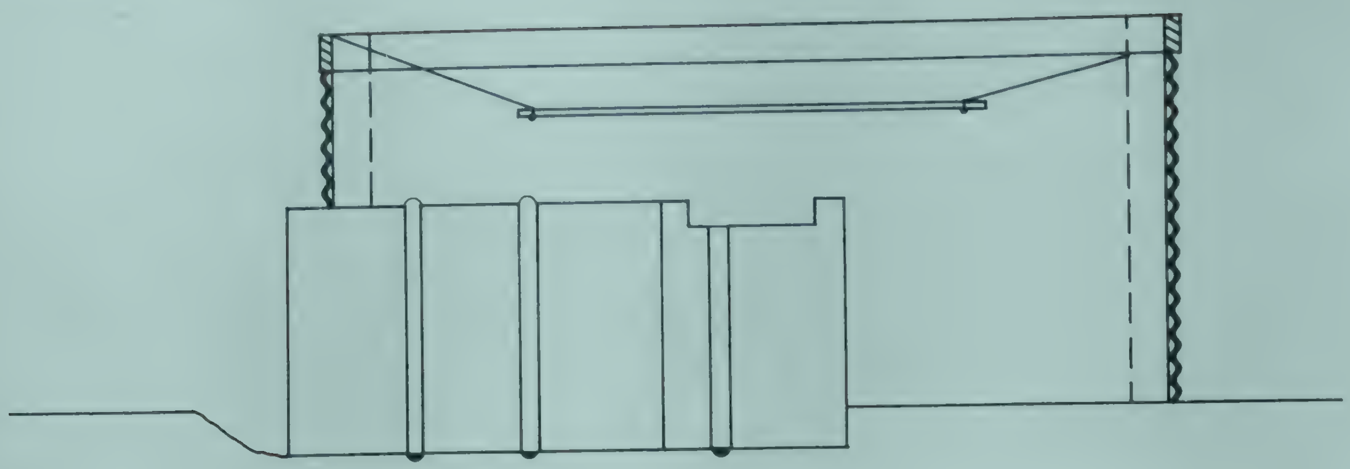
In the United Kingdom and other European countries, original products, developed in the Middle Ages, were heavily salted and smoked for some weeks. These products owed their long storage life, at normal temperatures, to a high salt concentration and to very long smoking and drying times. Modern transport and distribution facilities in the industrially developed countries have greatly reduced the need for long-term storage of smoked and dried fish and most products are now available for the consumer within a few days of processing. Smoke curing, as a method of food preservation, has also lost importance due to the rapid advances in freezing and cold storage techniques. Most smoked products in the developed world are only lightly cured in order to give them a mild savoury flavour. They will not remain in a wholesome condition much longer than fresh fish products when stored at normal temperatures and so should be refrigerated during storage.

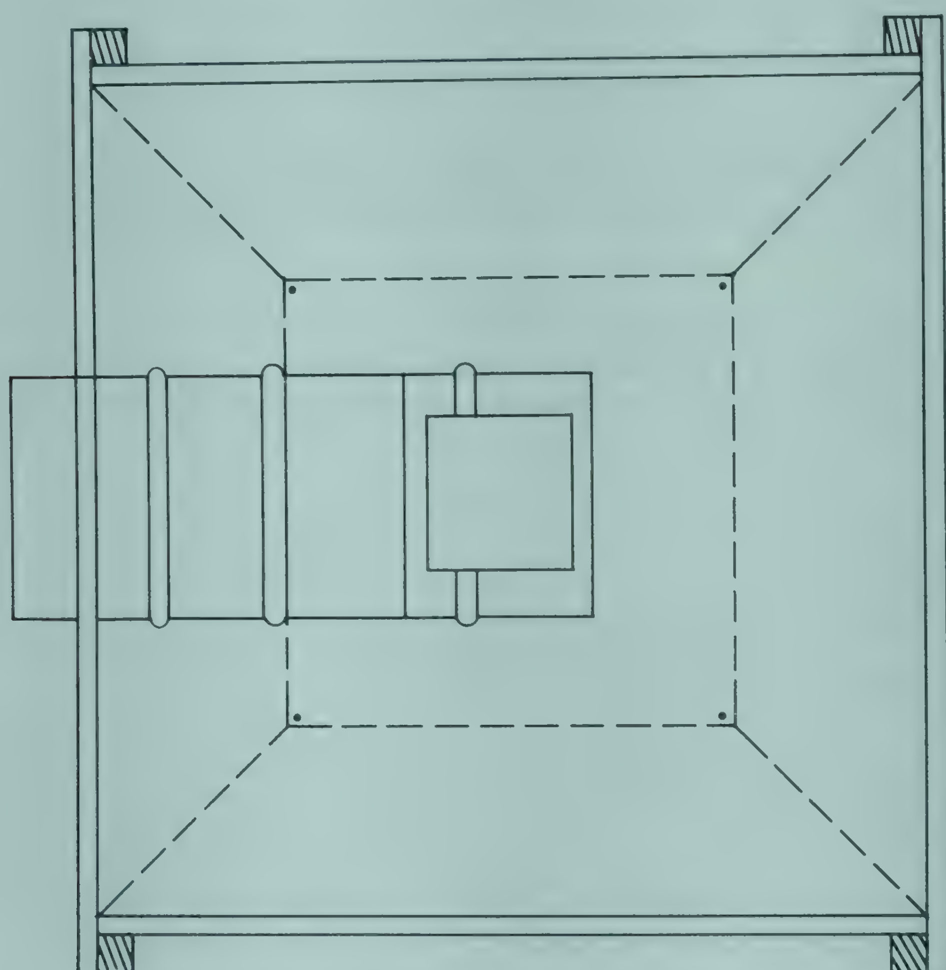
In most tropical developing fisheries, however, smoking is still used not only to impart desirable flavours but also to accelerate the drying process. Generally, smoked products will be dark brown in colour, hard and have a strong flavour. Smoking is often combined with a period of sun drying and/or preliminary brining. The temperature of smoking varies from place to place depending on consumer requisite and the type of smoking kiln or oven. Most products, however, are hot smoked, i.e. the temperature of smoking cooks the product.

Natural convection smokers

The apparatus used for smoking fish in traditional tropical fisheries is often fairly rudimentary. One of the simplest designs is a pit, dug in the ground, in which a fire is lit and the fish are laid on racks over the fire. Other traditional designs resemble

Figure 20
The Ivory Coast kiln





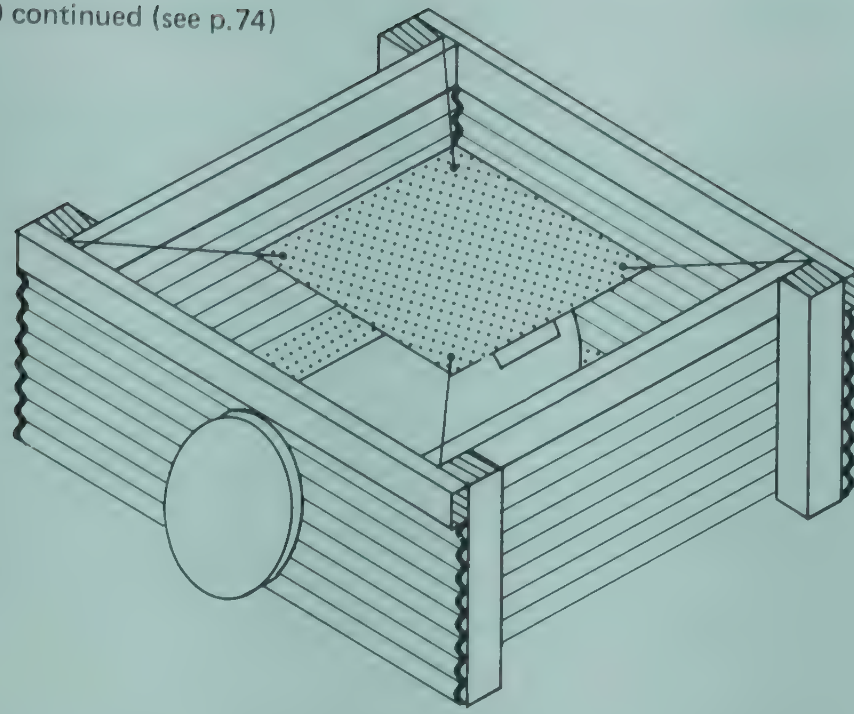
Source: Adapted from a drawing in 'A Short Guide to Fish Preservation with special reference to West African conditions' by G. C. Rawson (with chapter by F. A. Sai), Food and Agriculture Organization of the United Nations, Rome, 1966.

tables with open-work tops on which the fish are laid. Various ovens, constructed from local materials such as mud, sticks, stones and using relatively cheap man-made materials, such as old 44 gallon oil drums, scrap iron etc., are found in many different fisheries.

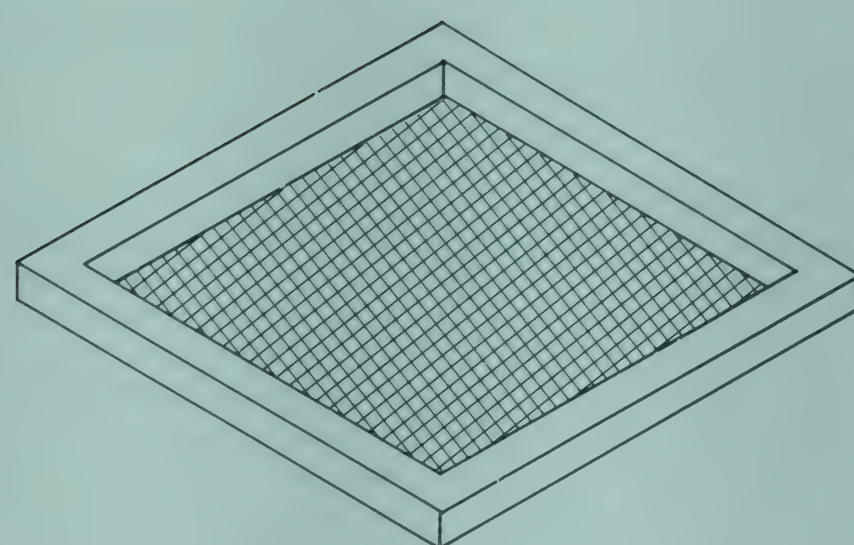
Some of these ovens and kilns are better than others but there are some disadvantages common to most:

- inefficient use of fuel
- difficult to control the fire and obtain a uniformly smoked product
- affected by adverse weather conditions
- low capacity
- materials used in construction are often inflammable
- constant attention is required to keep the fire burning or to control the smoking process

Figure 20 continued (see p.74)



GENERAL VIEW



RACK

However, in most instances the materials used in construction are cheap or freely available so capital costs are minimal.

To overcome these disadvantages several designs of kilns have been put forward as improvements. These include the 'Altona' ovens, first developed in West Africa, and the small smokers based on oil drums which can be used on board boats and for very small quantities of fish. The designs for these types of kiln are described in the FAO Fisheries Report No 88 and the FAO Fisheries Technical paper No 104*. One further design which is worth mentioning is the Ivory Coast kiln (Figure 20).

The Ivory Coast kiln is a development of the Altona kiln and was first produced in West Africa. It is fairly simple to construct and uses the minimum of expensive materials. It could be made in a variety of sizes and is suitable for use at village level in many fisheries.

The kiln itself consists of the following parts:

1. A walled enclosure, approximately 1 m high and from 1–2 m square in plan section, which can be constructed from a variety of materials. Locally available stones, cemented together with mud; a pole and mud construction; or four corner posts with sheet or corrugated metal for the sides, are some of the possible

*See References, p.79.

alternatives. The structure must be airtight and the top rim must be smooth and flat.

2. Into one side of the enclosure is set the fire box. This is most easily made from one or two old oil drums. For small kilns of about 1 m square, two 20-gallon drums are sufficient but, for larger kilns, 44-gallon drums will be needed. The drums are set on their sides so that an open end protrudes a few centimetres outside the square at ground level. The rest of the drum is inside the enclosure. The end of the drum inside the square remains closed, but a hole about 0.3 m square is cut in the uppermost surface of the drum. These details are most easily seen by referring to the diagrams. The square cut in the upper surface of the drum must be located centrally with the outer enclosure.

3. A square baffle sheet is suspended, above the hole in the oil drum, by wires from each of the four corners of the enclosure. This baffle consists of a sheet of iron, about twice the dimensions of the hole in the drum, which has holes of about 1 cm diameter punched all over it. The height of the baffle above the opening must be adjusted in use until a good distribution of smoke and heat is obtained.

4. The fish themselves are supported on racks above the enclosure. The racks are made from 7.5 cm square timber and chicken wire or expanded metal. The size of the racks is exactly the same as the square dimensions of the enclosure. The racks will rest on top of the walls of the enclosure and on top of one another. Four or five racks of fish can be smoked at once.

5. During smoking, the upper rack is covered with sheet metal or damp sacking; metal sheet is preferable for protection against rain.

Mechanical smokers

The traditional and improved smokers dealt with so far have no moving parts and rely on natural convection for air circulation. Mechanical kilns, by contrast, have fans or blowers to move the air across the fish. Such kilns are usually expensive to purchase and run but do give more control over smoking than other kilns. In most designs it is possible to accurately regulate the temperature of smoking and, to a lesser degree, the humidity of the air and the smoke density. With experienced operators it is possible to produce a consistent product time after time. For these reasons they are used quite extensively in the processing industries of Europe, the UK and North America for the production of products such as kippers, smoked haddock, buckling etc. The use of mechanical kilns for the production of smoked dried products is very limited.

SPECIFIC METHODS

There are many hundreds of different recipes for drying, salting and smoking. A few suggested procedures follow which have been found to be successful.

Ideally, only truly fresh fish should be used for salting and drying although in many instances drying is used as a last resort to save partially spoiled fish. If the fish cannot be processed shortly after capture they should be iced (or salted) before further processing.

Dried salt fish

1. Only fresh fish make a good product. Bleed mackerels, tunas etc. at sea; ice if possible or salt at sea.
2. Scale and split. Behead before splitting unless the heads are required.
3. Remove all but the tail third of the back bone.
4. Clean carefully. Remove all guts, liver, gills membranes.
5. Score the flesh as far as the skin but not through it.

6. Wash. Soak in 10 per cent brine for half an hour.

7. Drain.

8. Dry salt in a shallow box using appropriate amount of salt – more salt in thick parts of fish than thin parts – fill all scores, rub well in; one part of salt by weight to three parts fish is generally used. Saturated brine with an excess of salt may be used as an alternative to dry salting.

9. Place skin side down in the salting vat, making even piles. Top layer should have skin side up. If brine does not cover within 3–4 hours top up with saturated brine. Weight fish below surface, cover the vat.

10. Leave in salt for about 12 hours. Fish size, market preferences, weather and working conditions all affect salting time.

11. Wash in 10 per cent brine or sea water, removing all salt crystals.

12. Drain and set to dry. If drying conditions are good, dry in shade, not in open sun.

13. Leave on the drying racks during the first night. Thereafter, remove and pile up under pressure each night until drying is complete. Greater pressure and longer press times may be used towards the end of the drying period.

14. Continue alternate drying and pressing until no further weight is lost, Store and bale.

Boiled dried anchovies

This process could be used with suitable modifications for any small schooling species. The fish must be absolutely fresh, processing should start in the boats.

1. Wash and place in shallow baskets or trays; bamboo is a suitable material.

2. Cook in boiling brine (10° salinometer) for 50 to 90 seconds, rotating basket continually.

3. Drain and set to dry in trays.

4. Continue drying until hard dried. If bad weather intervenes store in chill rooms. Smoking may be possible if air drying cannot be used.

Tuna

Baked and smoked

1. Tuna are washed and eviscerated; then cut into chunks.

2. Hot-smoke overnight so that flesh is cooked.

3. Sun dry until hard; product can then be kept for several months.

Katsuobushi, Maldive fish, mas min, ikan kuyu

1. Small tunas e.g. skipjack are filleted.

2. Simmer fillets in dilute brine for 5 minutes. Alternatively, steam cook.

3. Smoke (cold-smoke or hot-smoke) for 8–12 hours.

4. Sun dry.

Mould growth may be deliberately encouraged, e.g., by storing before drying.

Watanabe's method of salting, smoking and drying

This is a method developed for use in Zambia where drying conditions are usually good. A satisfactory product can be made from fat fish.

1. Scale, gut and split. Clean very carefully.

2. Brine in saturated brine, small fish (½–2lbs) for 30–40 minutes, large fish 4–6 hours.

3. Wash.
4. Sun dry to three quarters of dressed weight; surface is dry and fish reasonably firm.
5. Smoke using smoke at 40°C to 60°C for 4–5 hours.
6. Sun dry to 35–46 per cent of dressed weight.

Keeping time is up to two months.

STORAGE

The nature of dried fish products presents particular problems during storage:

- dried fish are often brittle and easily damaged physically
- at high humidities, they absorb moisture and so become susceptible to spoilage by fungi and bacteria
- dried fish are susceptible to attack by insects, particularly beetles of the *Dermestes* group
- rats and mice as well as domestic animals are attracted to dried fish for food.

Most of the physical damage occurs during transport and consignments of dried fish should be packed in rigid containers which will not allow the fish to be crushed or shaken around. Many fisheries use hessian sacks, wicker baskets, cardboard cartons, brown paper and string and other soft materials which afford little protection. It is much better to use rigid wooden cartons or wooden boxes for the transportation of dried fish.

To prevent the uptake of moisture, plastic packaging materials are often put forward as a solution. These have various disadvantages, the main ones being:

- high cost
- they are easily punctured or damaged by sharp spines etc. on fish and therefore become useless
- sweating can occur inside the bag when there are changes in temperatures and this can produce moulds
- they do not usually give protection against insects

In most situations it is less costly and more feasible to store fish in well aerated shaded rooms or in a wooden box which allows the passage of air currents. If long storage times are required it may be necessary to re-dry the product periodically over a fire or in the sun.

Prevention of insect attack is particularly difficult but there are various means of control.

- salted fish are less susceptible to attack by insects than unsalted fish.
- infestation can be much reduced by screening the storage area against insects
- dermestid beetles often bore into wood and lay eggs, so producing a residual source of intestation. Wooden structures should be sprayed with a contact insecticide to overcome this problem.
- if infestation occurs, it is possible to drive out or kill the insects by hot smoking.
- the use of pyrethrum synergised with piperonyl butoxide as a dip or spray on dried fish will protect from insect attack (NB FAO/WHO maximum allowable residues are 3 ppm of pyrethrum and 20 ppm of piperonyl butoxide).
- good housekeeping is one of the most important factors which can help to prevent or control attacks by insects. Regular cleaning of storage areas will help to prevent cross-infestation between one batch and the next. Cross-infestation is especially high from hides and skins which are also attacked by *Dermestes*.

Construction of fish stores on stilts and thorough regular cleaning can help to prevent attack by mammalian pests.

Designs for a small 1 tonne store for dried fish and for some fish transport boxes are given in FAO Fisheries Technical Paper (104).

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Other methods of preservation and miscellaneous fishery products and by-products

In this session we will consider briefly two other methods of preservation, i.e. fermentation and canning, and a miscellaneous collection of fishery products and by-products.

FERMENTATION

Most traditional methods of preservation depend primarily on the removal of water from the fish by the action of sun and wind, often in conjunction with a salting or smoking process. In hot and humid (and wet) climates, however, spoilage is not always arrested by dehydration methods. Moreover, it was found that, if these changes were controlled, desirable flavours could be conferred to the product. These increased the acceptability of the fish and masked other less pleasant flavours and odours. The process is known as fermentation which is, in general terms, the breakdown of organic substances into simpler compounds by the action of enzymes or micro-organisms. The nature of the final product depends largely on the extent of fermentation.

During fermentation, salt inhibits the action of the natural bacteria of the fish and allows the fish enzymes to act (i.e. autolysis). Although fermentation is mainly autolytic, anaerobic bacteria have been shown to be responsible for the characteristic flavours and odours of some fermented fish products.

In South East Asia fermented fish products are extremely popular. Three types of product are made, i.e. fermented fish, fish pastes and fish sauces.

Fermented fish

The product is a partially fermented whole fish. Examples are 'Colombo-cured' fish of India, *pedah siam* of Thailand and *Makassar* fish of Indonesia. The raw material is fatty fish, generally mackerel species, and the process is in effect a pickle cure. In 'Colombo curing', the fish are washed, mixed with salt and an acid fruit pulp is added. Fermentation proceeds for 2—4 months, then the fish are packed in barrels and covered with the 'pickle' (for export). The product is reported to be stable for up to 1 year.

A number of kench-salted products, prepared in various countries, are partially fermented when sold and hence can be considered in this group.

Fermented fish pastes

Generally, small fish or shrimps are used; they are pounded before and during fermentation and, in some areas, a carbohydrate is added. Examples are *ngapi* of Burma, the various *mams* of Cambodia (now Kampuchea) and *belachan* or *trassi* of Malaysia and Indonesia. For pastes made for fish, 1 part salt to 3 parts fish may be used; in some products, the fish are eviscerated and beheaded. The sauce or pickle which forms on the surface may be sold separately. For shrimp pastes, the

shrimps are usually lightly salted and partially dried and then pounded. Fermented fish pastes are used as condiments.

Fermented fish sauces

If fermentation is allowed to continue beyond the stage at which pastes are made, the fish tissues break down to form a liquid with a residue of unfermented material. The liquid is fish sauce which is used as a condiment in much the same way as soy sauce. The methods of manufacture are often standardised within regions or villages but variations occur depending on local customs and the species of fish used. For examples, *budu,* in Malaysia, is made from small whole anchovies (*Stolephorus* spp) which are allowed to ferment for about 6 weeks (tamarind and sugar may also be added), and *patis,* in the Philippines, is made from anchovies or other fatty fish which are fermented for 3 months to 1 year. *Nuoc mam* of Vietnam is perhaps the most well-known sauce; the simplest method of preparation consists of mixing small fish with salt and pressing the mixture into an earthenware jar which is buried for several months. The sauce is then decanted. Commercial large-scale manufacture is more complex.

Fish sauces are clear liquids, ranging in colour from yellow to amber to darkish-brown, with a characteristic odour and flavour. Different grades are sold and quality is often based on colour rather than composition. Fish sauces are extremely stable and some will keep almost indefinitely.

Extensive research on methods of accelerating fermentation has been carried out but many of the processes have not proved successful because the final product lacks the typical aromas and flavours. Non-traditional methods of fermentation will not be dealt with here.

CANNING

Although the fish canning industry is more developed in the industrialised countries of the Northern hemisphere, a number of tropical countries produce a variety of canned fish products. Mexico and Brazil, for example, produce large quantities of canned fish, a large proportion of which is sold on the home market; Morocco is reported to be the largest producer of canned sardines in the world. Fish canneries in some of the developed countries use fish, particularly tuna, which were caught in tropical waters and frozen for shipment.

Canned fish have the potential of keeping almost indefinitely; the bacteria which cause deterioration are killed during the canning process and the fish cannot be subsequently re-infected. The canning process should aim at placing fish in the freshest possible condition into the can, removing the air by a heat treatment and hermetically sealing the lid and sterilising the can by further heat processing. The second heat treatment must be carried out at temperatures around 120°C; using steam under pressure or in autoclaves. The preparation of the fish and the canning operation itself vary according to the species used. Examples are given in the paper by Perovic*.

A canning industry should be considered only if the following are available:

- a regular supply and a large quantity of suitable fish (and other materials, e.g., salt, oil, etc.) at a reasonable price
- an adequate supply of cans at an economic price
- adequate manpower
- suitable infrastructure (energy, water, transport etc.)
- a market for the finished products.

Canning is always an expensive operation and it is therefore essential that careful consideration be given to the economics of production. In many countries, the high cost of cans has hindered the development of fish canning industries. The most profitable canning operations are based on canning of tunas, sardines, crustaceans and certain molluscs.

*See References, p.84.

MISCELLANEOUS FISHERY PRODUCTS AND BY-PRODUCTS

None of the products mentioned here is likely to form the basis of a major industry but all may be of importance in supplying a local market or a specialised export market. All are potential ways of adding to a fisherman's income. Also, they provide examples of the wide variety of fishery products which are available from the seas (and rivers) and of how parts of the fish, other than the flesh, can be prepared into useful 'by-products'. Some of these products are edible; most are prepared or processed by simple methods.

The range of invertebrates that is eaten by man is extensive. Whilst many of the practices which we have outlined in these lectures can be applied, time does not allow a detailed discussion on their handling and processing. They may be eaten fresh or sold as frozen or canned products; many are important export commodities. Simple drying techniques may be used for some. For example, oysters and shrimp may be sun dried and/or smoked.

Squids

Squids are prepared for drying by splitting the ventral side of the body and carefully removing the ink sac and internal 'shell'. The inside should be scraped and thoroughly washed before drying on racks. They must be turned at intervals. Drying may take up to 10 days by which time the finished product is almost translucent. Octopus may be treated similarly.

Sea cucumbers

Sea cucumbers, also known as bêche-de-mer, sea slugs or *trepang*, are sausage-shaped holothurians found in many tropical seas. They vary in size from about 15–70 cm and in colour, depending on species; some are smooth, others are covered with spicules. They are a delicacy amongst the Chinese.

Sea cucumbers spoil very rapidly and must therefore be eviscerated and processed as soon as possible after capture. Different methods of preparation and processing are used but, essentially, they are gutted after making a slit in the ventral surface, cleaned and boiled in sea water. They are then dried in the sun or over a fire.

Mollusc shells

There is still a small demand for mother-of-pearl shells (oysters, trochus, green snail). The shells must be undamaged, properly cleaned and must meet size specifications. Ornamental shells, such as cowries, cone shells etc., also have a limited market and cassis (conch) shells are used in Italy for the cameo trade.

Sponges

Although the use of natural sponges for cosmetic purposes and as 'bath' sponges has largely been replaced by synthetic plastic sponges, there is a limited demand for good quality sponges in certain specialised markets.

Shark fins

Shark fins are regarded as a delicacy by the Chinese; the cartilaginous fin rays are used to prepare soups flavoured with crab and chicken meat. The fins of all sharks over 6 ft long, except the nurse shark, are commercially valuable. The dorsal and caudal fins of sawfishes are also used. The fins should be cut off carefully, so that no meat is left attached, washed and hung out to dry. Large fins may take 14 or so days to dry under ideal conditions. The final moisture content should be around 7 to 8 per cent. Fins should be shipped in sets of dorsals, pectorals and the lower lobe of the caudal fin. Pale fins, so-called 'white' fins, fetch higher prices than the darker 'black' fins.

Bladders

Dried air bladders, also known as swim bladders, sounds or fish maws, are used by the Chinese as a base for making soups but their principal use is for making isinglass. Commercially, isinglass is important as a 'fining' agent used to clarify wines and beers. The bladders of only certain species are suitable, e.g. threadfins, jewfish, catfish, carp, and perches, and only large fish of 10 kg up to 45 kg are used. The whole bladders are removed, washed in cold fresh water and scraped clean. They are then dried flat or may be split and opened before sun drying. In humid climates they may be dried carefully over fires. The final product should be light in colour; therefore, the heat should not be intense and the smoke should be kept to a minimum.

Fish skins and scales

The use of fish skins should be considered only if they are a by-product from a processing operation or if they are from fish which are unacceptable as food fish. Possible uses are in making leather, glue or artificial pearls.

Leather. In the past, only shark skins have been used on a commercial basis. The shagreen (tooth-like 'scales') must be removed chemically. Because the skins are easily damaged, they are removed with underlying flesh and are then cleaned of adhering meat, salted and dried. They are then 'freshened' in cold water and, after brining and removal of the lime and elastin, are tanned. Porpoise and dolphin hides may also find a limited market.

Comparatively little work has been carried out on the 'curing' of the skins of tropical species.

Glue. A slow-setting glue, which is suitable for furniture making, book binding, etc., may be made from the skins of certain species; only thick skins are used. The skins are washed in cold water and cooked (in water) in steam-jacketed cookers. The liquid glue is then concentrated in open pans or in a vacuum evaporator to 50–55 per cent solids.

Artificial pearl. The scales of a variety of silvery fish contain guanine crystals. These crystals are brilliantly lustrous and are used in the making of artificial pearl essence. Scales may be collected from the bottom of the boats and stored in weak brine. The crystals are removed by mechanical scrubbing and centrifuging; they are then cleaned and suspended in a lacquer base which is used to coat glass beads. Pearl essence may also be used to give a 'lustre' to plastic items such as door handles, ashtrays etc.

It is unlikely that a developing country would find an export market for pearl essence but it could be used locally.

Fish roes

True 'caviar' is made from the female roe of sturgeon but inferior caviar may be made from the eggs of a number of fish such as salmon and cod. A number of tropical species could yield roes which are suitable for caviar substitutes. The roes are removed from freshly killed fish and rubbed gently through a sieve to remove the membranes. The eggs are mixed with salt (4–10 per cent by weight), stirred and left for 10–15 minutes; they are then drained and bottled and stored at chill temperatures or pasteurised.

Some female roes (e.g., from mullet, shad and Spanish mackerel) are salted and dried without removing the membranes. The roes may be dry or pickle salted (10 per cent salt by weight) and the salting time varies from 10 to 25 hours. After draining, the roes are sun-dried for 5–10 days; they may also be smoked. Keeping time depends on the extent of drying but it can be extended by dipping them in beeswax or a mixture of beeswax and paraffin wax (50:50).

Fish livers

Fish liver oils (particularly from cod and halibut) were formerly the major source of vitamins A and D; vitamin A is now produced synthetically. Sharks and tunas from tropical waters do, however, have livers rich in vitamins and the production of vitamin oils may be of interest to developing countries which import vitamin A.

Extraction of the oil must be from fresh livers; the livers can be stored frozen or by butt salting (10 per cent salt by weight). Livers with high oil content are usually steamed (85°C) or indirect heating (around 71°C) may be practised. Low oil content livers are treated with alkali, alkali/enzyme digestion and solvent extraction. Excessive heating must be avoided and, since vitamin A is inactivated by light, the oils must be stored in the dark.

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APPENDIX: FILMS SHOWN DURING THE COURSE

1.* 'Handling the Catch': Colour (10 mins) 1962
Illustrates good practice in handling the catch on a distant-water trawler.

Producer: Central Office of Information
Overseas Distribution Section
Hercules Road
London SE1 7DU

2.* 'Cold as Ice': Black and white (10 mins) 1960
Stresses the need for good icing of wet fish in the UK at all stages in the distribution chain.

Producer: Central Office of Information

3. 'Freezing Fish at Sea': Colour (14 mins) 1970
Demonstrates good practice in handling, freezing and storing the catch aboard a freezer trawler.

Producer & distributor: Central Office of Information

4.* 'Handling Frozen Fish': Colour (18 mins) 1969
Illustrates bad practices in handling fish before and after freezing on shore and during the distribution chain, and points out ways of improving these practices to maintain quality.

5. 'Allibert Plastic Fish Crates': Colour (22 mins)
Plastic stack/nest fish crates are shown to have many advantages over wooden and metal boxes. Their use in several French fishing ports is demonstrated.

Producer: The Allibert Co., France
Available from Film and TV Section
Food and Agriculture Organization of the United Nations,
Via delle Terme di Caracalla
00100 Rome
(Film No 282A, FAO Film Loans Catalogue)

6. 'Fish Spoilage Control': Colour (10 mins) 1957)
Animated cartoon illustrates the importance of care and hygiene in avoiding bacteriological contamination of fish at all stages of distribution. Correct methods of handling are shown.

Producer & Distributor: National Film Board of Canada
Available from: FAO (address as above)
(Film No 855, FAO Film Loans Catalogue)

7. 'Como se Produce el Bacalao': Black and white (10 mins) in Spanish
Demonstrates the production of salted cod in Norway for export to world markets. Shows handling onboard fishing vessels, processing stages on shore and transport in refrigerated vessels.

Producer: Toralf Sand, Norway
Distributor: Association of Norwegian Codfish Exporters
Available from: FAO (address as above)
(Film No 285, FAO Film Loans Catalogue)

* No longer in COI catalogue: can be borrowed from:
Torry Research Station
PO Box 31
135 Abbey Road
Aberdeen AB9 8DG, Scotland

8. 'The Key to Cleanliness': Colour (22 mins)
Demonstrates potential hazards from bad handling practices in handling foods. Illustrates that microbiological safety can be ensured through proper attention to cleanliness. The film is aimed at improving hygienic standards in food processing factories.

Producer: J Lyons & Co.
Hired from: Guild Sound & Vision Ltd.
Woodston House
Oundle Road
Peterborough PE2 9PZ

9. 'Fisheries Development on Lake Malawi': Colour (17 mins) 1976. Also available with Spanish commentary.
Illustrates co-operation between the Government of the Republic of Malawi, the Food and Agriculture Organization of the United Nations and the Tropical Products Institute in a fisheries development project.

Producer: Tropical Products Institute
Distributor: Central Office of Information (address as on page 85).

10. 'Shark Processing in the Caribbean': Colour (13 mins) 1972
Shows part of a UNDP/FAO fisheries development project, aided by Surinam Fisheries Foundation, in which shark are caught, processed and marketed. The shark meat is salted, dried and smoked or prepared as a smoked salmon substitute.

Producer & Distributor: UNDP/FAO
FAO (address as on p.85)
(Film No 860, FAO Film Loans Catalogue).

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